NOTICE!

ALL DRAWINGS
ARE LOCATED
AT THE END OF
THE DOCUMENT

DRAFT

PHASE III RI/FS WORK PLAN

ROCKY FLATS PLANT
881 HILLSIDE AREA
(OPERABLE UNIT NO. 1)

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM

FEBRUARY, 1990

Volume I – Text

DRAFT PHASE III REMEDIAL INVESTIGATION/FEASIBILITY STUDY

WORK PLAN

ROCKY FLATS PLANT
881 HILLSIDE AREA
(OPERABLE UNIT NO. 1)

ENVIRONMENTAL RESTORATION PROGRAM

U.S. Department of Energy
Rocky Flats Office
Golden, Colorado

FEBRUARY 1990

REVIEWED FOR CLASSIFICATION/UCNI
By George H. Setlock
Date 6/12/90

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

TABLE OF CONTENTS
(Continued)

APPENDICES

1.0 INTRODUCTION

This document presents the work plan for the Phase III Remedial Investigation/ Feasibility Study (RI/FS) of the 881 Hillside Area (Operable Unit No. 1) at the Rocky Flats Plant. It addresses characterization of contaminant sources as well as the nature and extent of contamination in soils, ground water, and surface water.

This investigation is part of a comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at the Rocky Flats Plant. These investigations are pursuant to the U.S. Department of Energy (DOE) Environmental Restoration (ER) Program [formerly known as the Comprehensive Environmental Assessment and Response Program (CEARP)], a Compliance Agreement between DOE, the U.S. Environmental Protection Agency (EPA) and the State of Colorado Department of Health (CDH) dated July 31, 1986, and a draft Inter-Agency Agreement (IAG) being developed among DOE, EPA, and CDH. The program developed by DOE, EPA, and CDH in response to the agreements addresses RCRA and CERCLA issues and has been integrated with the ER Program. In accordance with the draft IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" (RFI) and "Corrective Measures Study" (CMS).

1.1 ENVIRONMENTAL RESTORATION PROGRAM

The ER Program is designed to investigate and clean up contaminated sites at DOE facilities. The ER Program is being implemented in five phases. Phase 1 (Installation Assessment) includes preliminary assessments and site inspections to assess potential environmental concerns. Phase 2 (Remedial Investigations) includes planning and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites and evaluate potential contaminant migration pathways. Phase 3 (Feasibility Studies) evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified as needing correction in Phase 2. Phase 4 (Remedial Design/Remedial Action) includes design and implementation of site-specific remedial actions selected on the basis of Phase 3 feasibility studies. Phase 5 (Compliance and Verification) implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under Phase 4. Phase 1 has already been completed at Rocky Flats Plant (U.S. DOE, 1986), and Phases 2, 3, and 4 are currently in progress for Operable Unit No. 1 (881 Hillside Area).

Phase 2 activities at Operable Unit No. 1 include a Phase I and a Phase II RI. An initial (Phase I) field program was completed at the 881 Hillside Area in 1987, and a draft Phase I RI report was submitted to EPA and CDH in July 1987 (Rockwell International, 1987a). Based on results of that investigation, a second phase of field work was conducted at the 881 Hillside in the fall on 1987. A draft Phase II RI was submitted to EPA and CDH in March 1988 (Rockwell International, 1988a), and in October 1988, the U. S. DOE received written comments on the draft Phase II RI.

ER Program Phase 3 activities include submittal of a draft FS report to EPA and CDH in March 1988 (Rockwell International, 1988b). This document was submitted with the draft Phase II RI report, and EPA comments on the FS were received with the Phase II RI comments. Written responses to the March 1988 RI/FS were prepared and forwarded to EPA in February 1989 (Rockwell International, 1989a). A draft interim remedial action plan has also been developed to pump and treat contaminated alluvial ground water at Operable Unit No. 1 (U.S. DOE, 1990a). The plan was released for public comment during October and November 1989 and finalized in January 1990. Construction of the interim remedial action was started in January 1990. A final remedial action will be proposed based on Phase I, II, and III investigations.

1.2 WORK PLAN OVERVIEW

This Phase III RI/FS Work Plan for the 881 Hillside Area presents results of the Phase I and Phase II RIs; defines data quality objectives and data needs based on that investigation; specifies RI/FS tasks; and presents a Field Sampling Plan (FSP). The plan incorporates agency comments on the March 1988 RI/FS. This section (1.0 Introduction) presents site locations and descriptions, and Section 2.0 presents results of the previous RIs. Included in Section 2.0 are Phase I and Phase II characterization results for site geology and hydrology as well as the nature and extent of contamination in soils, ground water, surface water, and sediments. Section 3.0 discusses data quality objectives for the Phase III investigation. Section 4.0 specifies RI/FS tasks to be performed, and Section 5.0 presents the FSP to meet RI/FS objectives.

1.3 BACKGROUND AND PHYSICAL SETTING

1.3.1 Background

The Rocky Flats Plant is a government-owned, contractor-operated facility, which is part of the nationwide nuclear weapons production complex. The Plant was operated for the U.S. Atomic Energy Commission (AEC) from its inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for the Plant was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the DOE in 1977. Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975. Rockwell International was the prime contractor responsible for operating the Rocky Flats Plant from July 1, 1975, until December 31, 1989. E G & G Rocky Flats, Inc., became the prime contractor at the Rocky Flats Plant on January 1, 1990.

1.3.1.1 Plant Operations

The primary mission of the Rocky Flats Plant is to fabricate nuclear weapon components from plutonium, uranium, and other non-radioactive metals (principally beryllium and stainless steel). Parts made at the Plant are shipped elsewhere for assembly. In addition, the Plant reprocesses components after they are removed from obsolete weapons for recovery of plutonium.

Both radioactive and nonradioactive wastes are generated in the production process. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility. However, both storage and disposal of hazardous and radioactive wastes occurred on site in the past. Preliminary assessments under the ER Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

1.3.1.2 Previous Investigations

Various studies have been conducted at the Rocky Flats facility to characterize environmental media and to assess the extent of radiological and chemical contaminant releases to the environment. The investigations performed prior to 1986 are summarized in Rockwell International (1986a) and include:

1) Detailed descriptions of the regional geology (Malde, 1955; Spencer, 1961; Scott, 1960, 1963, 1970, 1972 and 1975; Van Horn, 1972 and 1976; U.S. DOE, 1980; Dames and Moore, 1981; and Robson et al., 1981a and 1981b).

2) Several drilling programs beginning in 1960 that resulted in the construction of approximately 60 monitor wells by 1982;

3) An investigation of surface and ground water flow systems by the U.S. Geological Survey (Hurr, 1976);

4) Environmental, ecological, and public health studies which culminated in an environmental impact statement (U.S. DOE, 1980);

5) A summary report on ground-water hydrology using data from 1960 to 1985 (Hydro-Search, Inc., 1985);

6) A preliminary electromagnetic survey of the Plant perimeter (Hydro-Search, Inc., 1986);

7) A soil gas survey of the Plant perimeter and buffer zone (Tracer Research, Inc., 1986); and

8) Routine environmental monitoring programs addressing air, surface water, ground water, and soils (Rockwell International, 1975 through 1985, 1986b, and 1987b).

In 1986, two major investigations were completed at the Plant. The first was the ER Program Phase 1 installation assessment (U.S. DOE, 1986) which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. A number of sites were identified that could potentially have adverse impacts on the environment. These sites were designated as solid waste management units (SWMUs) by Rockwell International (1987c) and were divided into three categories:

1) hazardous waste management units that will continue to operate and need a RCRA operating permit,

2) hazardous waste management units that will be closed under RCRA interim status, and

3) inactive waste management units that will be investigated and cleaned up under Section 3004(u) of RCRA or CERCLA. No RCRA or CERCLA regulatory distinction in the use of the terms "site", "unit", or "SWMU" is intended in this document.

The second major investigation completed at the Plant in 1986 involved a hydrogeologic and hydrochemical characterization of the entire Plant site. Plans for this study were presented in Rockwell International (1986c and 1986d), and study results were reported in Rockwell International (1986e). Investigation results indicated four areas to be significant contributors to environmental contamination, with each area containing several sites. The areas are the 881 Hillside Area, the 903 Pad Area, the Mound Area, and the East Trenches Area.

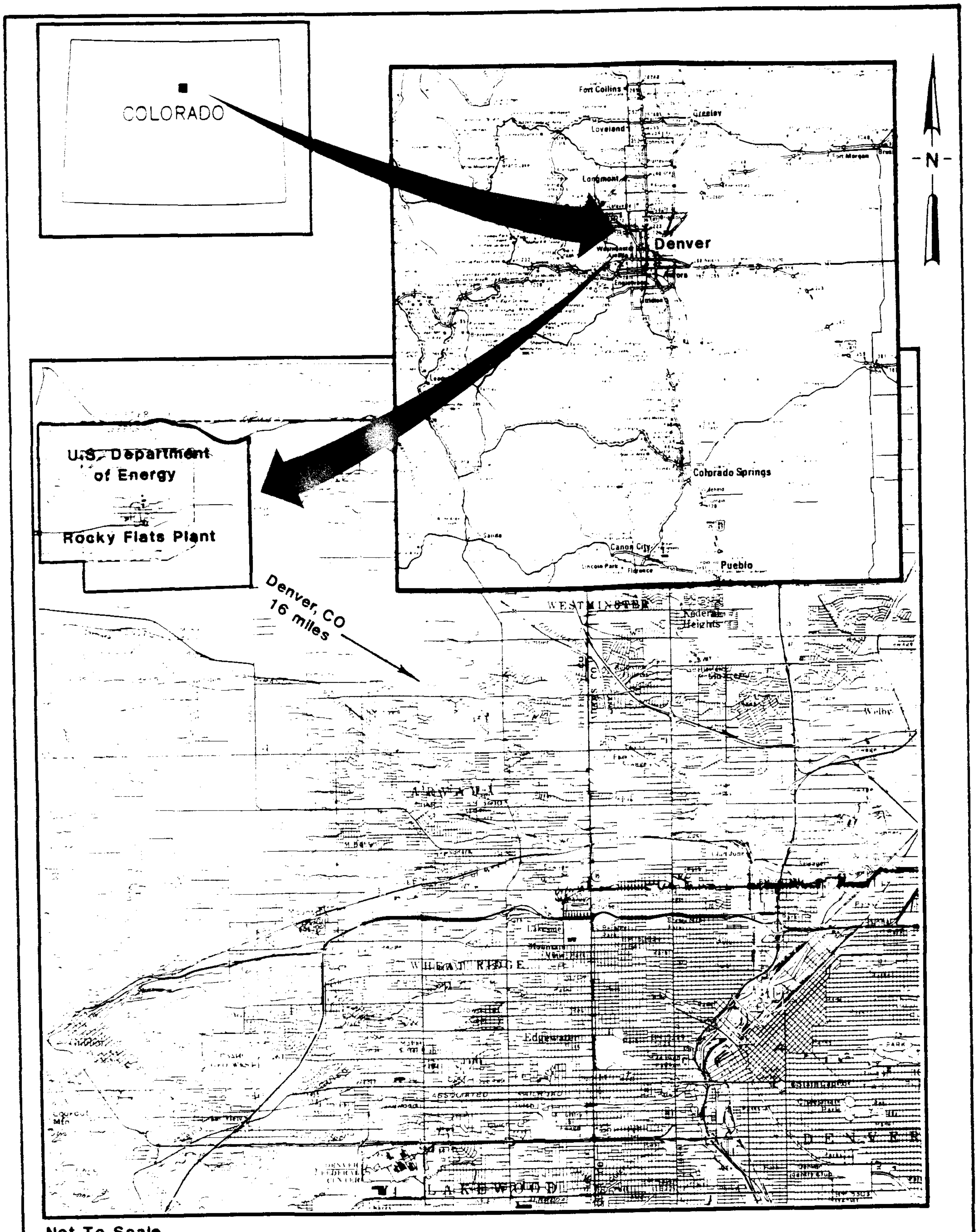
Sites at the 881 Hillside Area were selected as High Priority Sites because of the elevated concentrations of volatile organic compounds detected in the ground water, the relatively permeable soils, and the proximity of the area to a surface water drainage. RI/FS activities for the 881 Hillside Area (Operable Unit No. 1) have been previously noted in Section 1.1.

1.3.2 Physical Setting

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1). The Plant consists of approximately 6,550 acres of federally owned land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the Plant security area of approximately 400 acres. The security area is surrounded by a buffer zone of approximately 6,150 acres (Figure 1-2).

1.3.2.1 Topography

The natural environment of the Plant and vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. The Plant is directly east of the north-south trending Rocky Mountains, with an elevation of approximately 6,000 feet above sea level. Rocky Flats Plant is located on a broad, eastward sloping plain of overlapping alluvial fans developed along the Front Range. The fans extend about five miles in an eastward direction from their origin in the abruptly rising Front Range and terminate on the east at a break in slope to low rolling hills. The continental divide is about 16 miles west of the Plant. The operational area at the Plant is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek).



Not To Scale

Figure 1-1: **Location of Rocky Flats Plant**

1.3.2.2 Surface Water Hydrology

Three intermittent streams drain the Rocky Flats Plant with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2). Rock Creek drains the northwestern corner of the Plant and flows northeast through the buffer zone to its off-site confluence with Coal Creek. An east-west trending topographic divide bisects the Plant separating the Walnut and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the Plant security area. These three forks of Walnut Creek join in the buffer zone and flow to Great Western Reservoir approximately one mile east of the confluence. Woman Creek drains the southern Rocky Flats Plant buffer zone flowing eastward to Standley Reservoir. The South Interceptor Ditch lies between the Plant and Woman Creek. The South Interceptor Ditch collects runoff from the southern Plant security area and diverts it to Pond C-2, where it is monitored in accordance with the Plant National Pollutant Discharge Elimination System (NPDES) permit prior to discharge to Woman Creek.

1.3.2.3 Regional and Local Hydrogeology

Geologic units at the Rocky Flats Plant (in descending order) are the surficial units (Rocky Flats Alluvium, various terrace alluviums, valley fill alluvium, and colluvium) (Figure 1-3) and bedrock (Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone) (Figure 1-4). Ground water occurs under unconfined conditions in both the surficial and bedrock units. In addition, confined ground-water flow occurs in bedrock sandstones.

<u>Rocky Flats Alluvium</u>

The Rocky Flats Alluvium underlies a large portion of the Plant. The alluvium is a broad planar deposit consisting of a topsoil layer underlain by up to 100 feet of silt, clay, sand, and gravel. Unconfined ground-water flow occurs in the Rocky Flats Alluvium which is relatively permeable. Recharge to the alluvium is from precipitation, snowmelt, and water

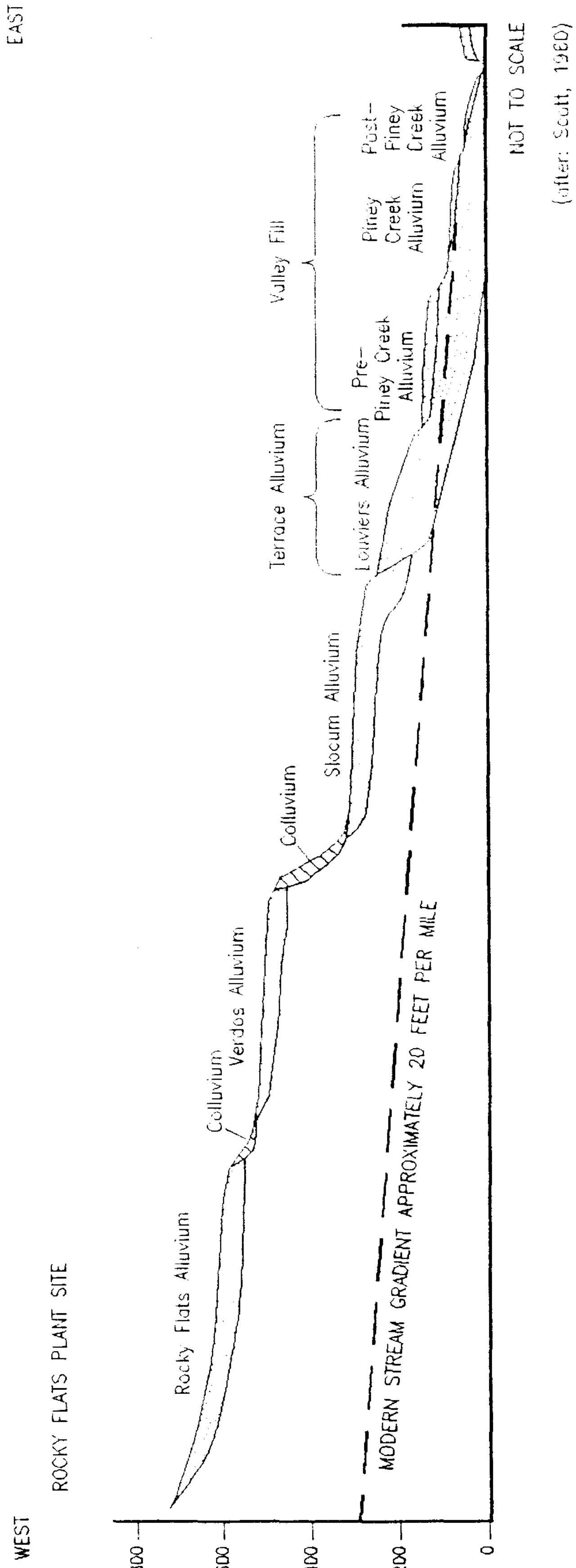
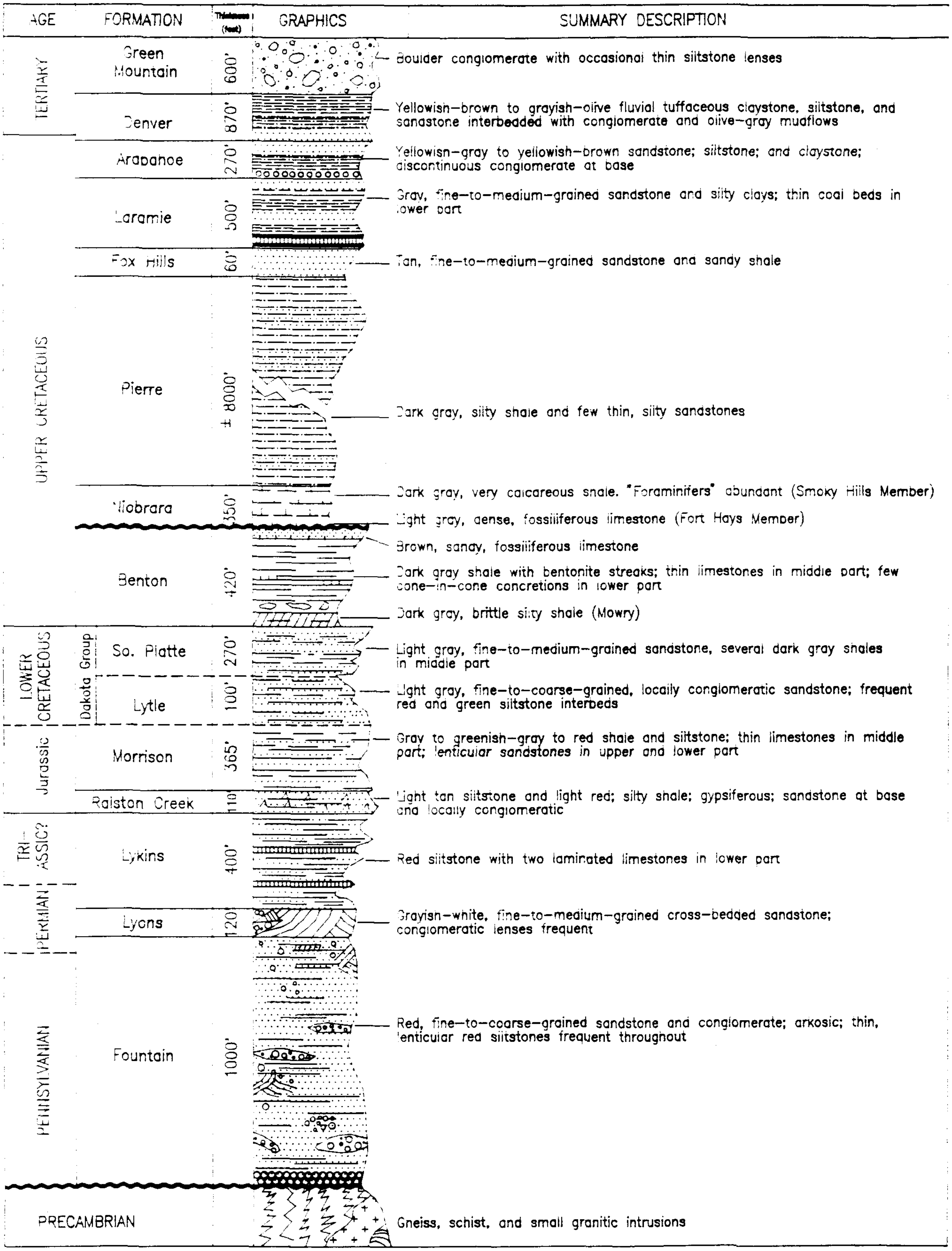


FIGURE 1-3
EROSIONAL SURFACES AND ALLUVIAL DEPOSITS
EAST OF THE FRONT RANGE, COLORADO

R33014.pj-011990



(modified from: LeRoy and Weimer, 1971)

FIGURE 1-4

GENERALIZED STRATIGRAPHIC SECTION

881-90F.PJ-020190

losses from ditches, streams, and ponds that are cut into the alluvium. General water movement in the Rocky Flats Alluvium is from west to east and towards the drainages. Ground-water flow is also controlled by buried channels in the top of bedrock. The water table in the Rocky Flats Alluvium rises in response to recharge during the spring and declines during the remainder of the year. Discharge from the alluvium occurs at minor seeps in the colluvium that covers the contact between the alluvium and bedrock along the edges of the valleys. The Rocky Flats Alluvium thins east of the Plant boundary and does not directly supply water to wells located downgradient of Rocky Flats Plant.

Other Alluvial Deposits

Various other alluvial deposits occur topographically below the Rocky Flats Alluvium in the Plant drainages. Colluvium (slope wash) mantles the valley side slopes between the Rocky Flats Alluvium and the valley bottoms. In addition, remnants of younger terrace deposits including the Verdos, Slocum, and Louviers Alluvia occur occasionally along the valley side slopes. Recent valley fill alluvium occurs in the active stream channels.

Unconfined ground-water flow occurs in these surficial units. Recharge is from precipitation, percolation from streams during periods of surface water runoff, and by seeps discharging from the Rocky Flats Alluvium. Discharge is by evapotranspiration and by seepage into other geologic formations and streams. The direction of ground-water flow is generally downslope through colluvial materials and then along the course of the stream in valley fill materials. During periods of high surface water flow, water is lost to bank storage in the valley fill alluvium and returns to the stream after the runoff subsides.

Arapahoe Formation

The Arapahoe Formation underlies surficial materials beneath the Plant. The Arapahoe consists of claystone with thin lenticular sandstones. Total formation thickness varies up to 270 feet (Robson et. al., 1981a). The permeable zones of the Arapahoe are lenticular sandstones within the claystone. The lenticular sand bodies are composed of fine-grained sands and silts, and their hydraulic conductivity is low compared to the overlying Rocky Flats Alluvium. A seismic inflection survey is currently being implemented at the Plant to further characterize bedrock geology.

The Arapahoe Formation is recharged by leakage from streams and ground-water movement from overlying surficial deposits. The main recharge areas are under the Rocky Flats Alluvium, although some recharge from the colluvium and valley fill alluvium likely occurs along the stream valleys. Recharge is greatest during the spring and early summer when rainfall and stream flow are at a maximum and water levels in the Rocky Flats Alluvium are high. Ground-water movement in the Arapahoe Formation is generally toward the east; although flow within individual sandstones is not fully characterized at this time. Regionally, ground-water flow in the Arapahoe Formation is toward the South Platte River in the center of the Denver Basin (Robson et al., 1981a).

Laramie Formation and Fox Hills Sandstone

The Laramie Formation underlies the Arapahoe and is composed of two units, a thick upper claystone and a lower sandstone. The claystone is greater than 700 feet thick and is of very low hydraulic conductivity; therefore, the U.S. Geologic Survey (Hurr, 1976) concludes that Plant operations will not impact any units below the upper claystone unit of the Laramie Formation.

The lower sandstone unit of the Laramie Formation and the underlying Fox Hills Sandstone comprise a regionally important aquifer in the Denver Basin known as the Laramie-Fox Hills Aquifer. These units subcrop west of the Plant and can be seen in clay pits excavated through the Rocky Flats Alluvium. The steeply dipping beds of these units quickly flatten to the east. Recharge to the aquifer occurs along the rather limited outcrop area exposed to surface water flow and leakage along the Front Range (Robson et al., 1981b).

1.3.2.4 Meteorology

The area surrounding the Rocky Flats Plant has a semiarid climate characteristic of much of the central Rocky Mountain region. Approximately forty percent of the 15-inch annual precipitation falls during the spring season, much of it as wet snow. Thunderstorms (June to August) account for an additional thirty percent of the annual precipitation. Autumn and winter are drier seasons, accounting for nineteen and eleven percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (U.S. DOE, 1980).

Special attention has been focused on dispersion meteorology surrounding the Plant due to the remote possibility that significant atmospheric releases might affect the Denver metropolitan area. Studies of air flow and dispersion characteristics (e.g., Hodgin, 1983 and 1984) indicate that drainage flows (winds coming down off the mountains to the west) turn and move toward the north and northeast along the South Platte River valley and pass to the west and north of Brighton, Colorado (U. S. DOE, 1986).

1.3.2.5 Surrounding Land Use and Population Density

The Rocky Flats Plant is located in a rural area. Approximately 50 percent of the area within ten miles of the Rocky Flats Plant is in Jefferson County. The remainder is located in Boulder County (40 percent) and Adams County (10 percent). According to the 1973 Colorado Land Use Map, 75 percent of this land was unused or was used for agriculture. Since that time, portions of this land have been converted to housing, with several new housing subdivisions being started within a few miles of the buffer zone. One such subdivision is located south of the Jefferson County Airport and several are located southeast of the Plant.

A demographic study using 1980 census data shows that approximately 1.8 million people lived within 50 miles of the Rocky Flats Plant in 1980 (Rockwell International, 1987b). Approximately 9,500 people lived within five miles of the Plant in 1980. The most populous sector was to the southeast, toward the center of Denver. This sector had a 1980 population of about 555,000 people living between 10 and 50 miles from Rocky Flats. Recent population estimates registered by the Denver Regional Council of Governments (DRCOG) for the eight county Denver metro region have shown distinct patterns of growth between the first and second halves of the decade. Between 1980 and 1985, the population of the eight county region increased by 197,890, a 2.4 percent annual growth rate. Between 1985 and 1989 a population gain of 71,575 was recorded, representing a 1.0 percent annual increase (the national average). The 1989 population showed an increase of 2,225 (or 0.1 percent) from the same date in 1988 (DRCOG, 1989).

There are eight public schools, within six miles of the Rocky Flats Plant. The nearest educational facility is the Witt Elementary School, which is approximately 2.7 miles east of the Plant buffer zone. The closest hospital is Centennial Peaks Hospital located approximately seven miles northeast. The closest park and recreational area is the Standley Lake area, which is approximately five miles southeast of the Plant. Boating, picnicking, and limited overnight camping are permitted. Several other small parks exist in communities within ten miles. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres of general camping and outdoor recreation. Other national and state parks are located in the mountains west of the Rocky Flats Plant, but all are more than 15 miles away.

Some of the land adjacent to the Plant is zoned for industrial development. Industrial facilities within five miles include the TOSCO laboratory (40-acre site located two miles south), the Great Western Inorganics Plant (two miles south), the Frontier Forest Products yard (two miles south), the Idealite Lightweight Aggregate Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (990-acre site located 4.8 miles northeast).

Several ranches are located within ten miles of the Plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses. According to the 1987 Colorado Agricultural Statistics, 20,758 acres of crops were planted in Jefferson County (total land area of approximately 475,000 acres) and 68,760 acres of crops were planted in Boulder County (total land area of 405,760 acres). Crops consisted of winter wheat, corn, barley, dry beans, sugar beets, hay, and oats. Livestock consisted of 5,314 head of cattle, 113 hogs, and 346 sheep in Jefferson County, and 19,578 head of cattle, 2,216 hogs, and 12,133 sheep in Boulder County (Post, 1989).

1.3.2.6 Ecology

A variety of vegetation thrives within the Plant boundary. Included are species of flora representative of tall grass prairie, short grass plains, lower montane, and foothill ravine regions. None of these vegetative species are on the endangered species list. It is evident that the vegetative cover along the Front Range of the Rocky Mountains has been radically altered by human activities such as burning, timber cutting, road building, and overgrazing for many years. Since the acquisition of the Rocky Flats Plant property, vegetative recovery has occurred as evidenced by the presence of disturbance sensitive grasses species like big bluestem (Andropogon gerardii) and sideoats grama (Bouteloua curtipendula). No vegetative stresses attributable to hazardous waste contamination have been identified (U.S. DOE, 1980).

The animal life inhabiting the Rocky Flats Plant and its buffer zone consists of species associated with western prairie regions. The most common large mammal is the mule deer (Odocoileus lemionus), with an estimated 100-125 permanent residents. There are a number of small carnivores, such as the coyote (Canis latrans), red fox (Vulpes fulva), striped skunk (Mephitis mephitis), and long-tailed weasel (Mustela frenata). A profusion of small herbivores can be found throughout the Plant and buffer zone consisting of species such as the pocket gopher (Thomomys sp. and Perognathus sp.), white-tailed jackrabbit (Lepus townsendii), and the meadow vole (Microtus pennsylvanicus) (U.S. DOE, 1980).

Commonly observed birds include western meadowlarks (Sturnella neglecta), horned larks (Eremophila alpestris), mourning doves (Zenaidura macroura), and vesper sparrow (Pooecetes gramineus). A variety of ducks, killdeer (Charadrius vociferus), and red-winged black birds (Agelaius phoeniceus) are seen in areas adjacent to ponds. Mallards (Anas platyrhynochos) and other ducks (Anas sp.) frequently nest and rear young on several of the ponds. Common birds of prey in the area include marsh hawks (Circus cyaneus), red-tailed hawks (Buteo jamaicensis), ferruginous hawks (Buteo regalis), rough-legged hawks(Buteo lagopus), and great horned owls (Bubo virginianus) (U.S DOE, 1980).

Bull snakes (Pituophis melanoleucus) and rattlesnakes (Crotalus sp.) are the most frequently observed reptiles. Eastern yellow-bellied racers (Coluber constrictor) have also been seen. The eastern short-horned lizard (Phrynosoma douglassi brevirostre) has been reported on the site, but these and other lizards are not commonly observed. The western painted turtle (Chrysemys picta) and the western plains garter snake (Thamnophis radix) are found in and around many of the ponds (U.S. DOE, 1980).

1.4 881 HILLSIDE SITE LOCATIONS AND DESCRIPTIONS

This RI/FS Work Plan addresses the 881 Hillside Area located on the south side of the Rocky Flats Plant security area. These sites were designated high priority sites because of their suspected relationship to ground-water contamination (U.S. DOE, 1987a). Several sites are included in the area because of their physical proximity to each other. Figure 1-5 shows the location of the 881 Hillside Area and presents the site locations within the area.

Twelve sites are located within the 881 Hillside Area. These sites are:

- Oil Sludge Pit Site (SWMU Ref. No. 102);
- Chemical Burial Site (SWMU Ref. No. 103);
- Liquid Dumping Site (SWMU Ref. No. 104);
- Out-of-service Fuel Oil Tank Sites (SWMU Ref. Nos. 105.1 and 105.2);
- Outfall Site (SWMU Ref. No. 106);
- Hillside Oil Leak Site (SWMU Ref. No. 107);
- Multiple Solvent Spill Sites (SWMU Ref. Nos. 119.1 and 119.2);
- Radioactive Site - 800 Area Site #1 (SWMU Ref. No. 130);

- Sanitary Waste Line Leak Site (SWMU Ref. No. 145); and
- Building 885 Drum Storage Site (SWMU Ref. No. 177).

The site descriptions presented in the following sections are taken from the Rocky Flats Plant CEARP Phase I Report (U.S. DOE, 1986), the RCRA Part B Operating Permit Application (Rockwell International, 1987c), and the Phase II Remedial Investigation Report for High Priority Sites (Rockwell International, 1988a). The following descriptions are also based on a more recent review of historical aerial photography.

1.4.1 Oil Sludge Pit Site (SWMU Ref. No. 102)

Approximately 30 to 50 drums of oil sludge were emptied into a pit south of Building 881 in the late 1950s, and the pit was later covered (Rockwell International, 1987c). The sludge was reportedly collected during cleaning of the two No. 6 fuel oil tanks south of Building 881 (SWMU Ref. Nos. 105.1 and 105.2) in 1958 based on interviews with Plant personnel (Rockwell International, 1987c). However, the pit appears to have been in existence in 1955 based on aerial photography of the area. In the 1955 photos, the oil sludge pit is located approximately 500 feet south of Building 881 and measures approximately 40 feet by 70 feet in dimension. The pit appears to contain oily liquids, and seepage from the pit is evident. Also apparent on the 1955 photo is a small pond adjacent to Woman Creek. Drainage from the Oil Sludge Pit Site appears directed toward this pond. The oil sludge pit was covered after its use (Rockwell International, 1987c), and the pit and seepage is no longer visible on 1959 aerial photographs.

1.4.2 Chemical Burial Site (SWMU Ref. No. 103)

An area south of Building 881 was reportedly used to bury unknown chemicals (U. S. DOE, 1986). The exact location, dates of use, and contents of the site are unknown. This site was originally thought to be located in the same area as the Oil Sludge Pit Site (Rockwell International, 1987c). However, a pit apparently filled with liquid is evident approximately

150 feet southeast of Building 881 on 1963 aerial photographs. This pit is roughly circular on the photos and measures approximately 50 feet in diameter.

1.4.3 Liquid Dumping Site (SWMU Ref. No. 104)

An area east of Building 881 was reportedly used for disposal of unknown liquids and for disposing of empty drums prior to 1969 (U. S. DOE, 1986). A pit was reported with plan dimensions of approximately 50 by 50 feet based on 1965 aerial photographs (Rockwell International, 1987c). However, further review of these historical aerial photos indicates the identified "pit" may be a shadow on the photo. The Liquid Dumping Pit Site is likely the same location as the Chemical Burial Site; however, the area originally identified as the Liquid Dumping Pit will also undergo additional investigation to verify its absence.

1.4.4 Out-of Service Fuel Tank Sites (SWMU Ref. Nos. 105.1 and 105.2)

Two out-of-service No. 6 fuel oil tanks are located immediately south of Building 881 (Figure 1-6). Asbestos was placed in the two tanks and they were later filled with concrete (U. S. DOE, 1986). The exact dates of these activities are unknown; however, they apparently occurred subsequent to use of the fuel oil storage tanks (1958 through 1976) (Rockwell International, 1987c).

1.4.5 Outfall Site (SWMU Ref. No. 106)

A six-inch diameter vitrified clay pipe outfall existed south of Building 881 which discharged water in December 1977. Previous reports indicated that this was a cleanout pipe for an overflow line from the Building 881 cooling tower (Rockwell International, 1987c). However, review of construction drawings during the Phase II RI indicated that the pipe is an overflow line from the sanitary sewer sump in Building 887 (Figure 1-6).

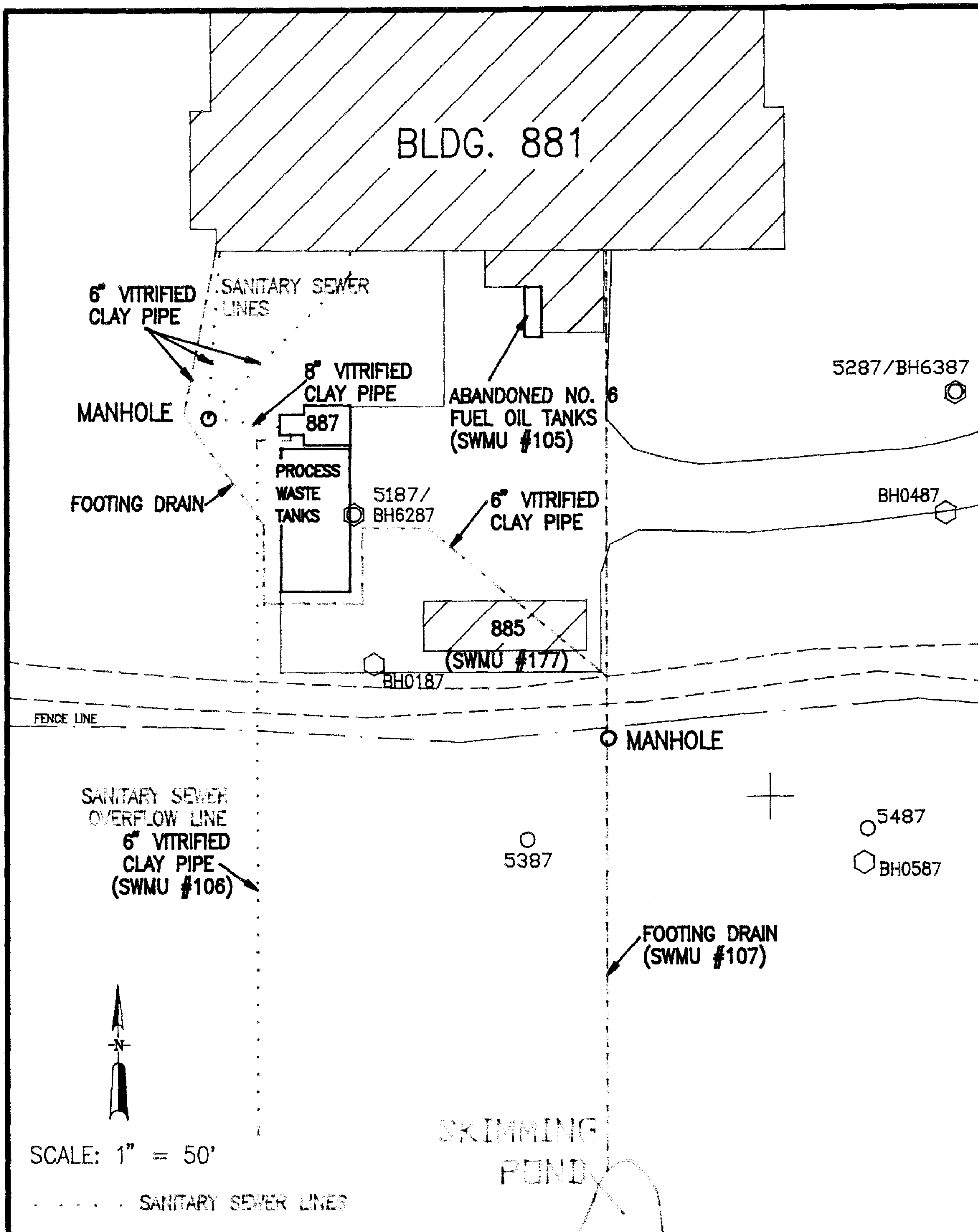


FIGURE 1-6
ENLARGEMENT OF SWMUS 105, 106, 145, AND 177

RF50B.PJ-013090

1.4.6 Hillside Oil Leak Site (SWMU Ref. No. 107)

In May 1973, an oil leak was discovered on the hillside south of Building 881. The source of the oil was believed to be the two No. 6 fuel oil tanks (SWMUs 105.1 and 105.2) south of the building; however, pressure testing of the tanks and associated lines did not reveal any leaks (Rockwell International, 1987c). The oil spill was contained with straw, and the straw and soil were removed and disposed of in the present landfill north of the Plant (Rockwell International, 1987c).

It was later discovered that the oil had emerged through the Building 881 footing drain outfall (Figure 1-6). A ditch and concrete skimming pond were built below the footing drain outfall to contain the oil (Owen and Steward, 1973). These structures are still present, although no oil has been observed in the outfall since 1973 (Rockwell International, 1987c).

1.4.7 Multiple Solvent Spill Site (SWMU Ref. Nos. 119.1 and 119.2)

Beginning in 1967, two areas east of Building 881 and along the southern perimeter road were used as barrel storage areas. The barrels contained unknown quantities and types of solvents and wastes. The two facilities were expanded between 1967 and 1971, with major expansion occurring in 1969. Barrel storage in these areas was discontinued, and all barrels were removed by 1972. The exact types and quantities of solvents stored at this facility are unknown (Rockwell International, 1987c). SWMU 119.1 is the larger western barrel storage area, and SWMU 119.2 is the eastern barrel storage area. The site boundaries shown on Figure 1-5 represent the extent of soil disturbance associated with the sites. Actual barrel storage areas within each site are also shown.

1.4.8 Radioactive Site - 800 Area #1 (SWMU Ref. No. 130)

An area east of Building 881 and northwest of SWMU 119.1 was used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium. The materials at this site were derived from three sources on Plant site.

In September 1969 approximately 320 tons [250 cubic yards (Illsley, 1978)] of plutonium contaminated soil and asphalt were removed from the west side of Building 776 and placed on the 881 Hillside (Owen and Steward, 1973). The soil and asphalt were contaminated during the May 11, 1969, fire in building 776, and had an estimated average plutonium activity of 7.4 disintegrations per minute per gram (dpm/g) [3.36 picoCuries per gram (pCi/g)]. The total plutonium concentration of this material was estimated to be 14 milligrams (mg) [859 microCuries (μCi)] (Putzier, 1970). Material from the 1969 fire was buried under one to two feet of fill dirt (Owen and Steward, 1973).

In August 1970, a section of the Central Avenue roadway between Eighth and Tenth Streets was removed and placed on the 881 Hillside at SWMU 130 (Owen and Steward, 1973). This stretch of road was radioactively contaminated in June 1968 by a leaking drum in transit from the 903 Drum Storage Site to Building 774 (Owen and Steward, 1973). The exact quantity and radioactivity of the material removed from Central Avenue are unknown.

The third episode of soil disposal at SWMU 130 occurred in 1972 (Owen and Steward, 1973). Approximately 60 cubic yards of plutonium contaminated soil were removed from around the Building 774 process waste tanks and placed on the 881 Hillside (Owen and Steward, 1973). The soil was placed on top of previously deposited soils at SWMU 130 and covered with approximately three feet of fill dirt (Illsley, 1978). The estimated total long lived alpha activity of this soil is less than 250 dpm/g (Illsley, 1978).

1.4.9 Sanitary Waste Line Leak Site (SWMU Ref. No. 145)

The four-inch cement-asbestos sanitary sewer line located south of Building 881 leaked in January 1981. An earthen dike was constructed to prevent the spill from entering the South Interceptor Ditch, and the line was repaired. The line conveyed sanitary wastes to the sanitary treatment plant and did not carry hazardous or radioactive materials. Conveyance of laundry wastewater, which may have contained low levels of radioactive materials, was discontinued in 1973 (Rockwell International, 1987c). Review of Building 881 construction drawings indicates that the only sanitary waste lines presently located south of the building are the six-inch overflow line from Building 887 (SWMU 106) and an eight-inch vitrified clay pipe which runs east-west into Building 887 (Figure 1-6).

1.4.10 Building 885 Drum Storage Site (SWMU Ref. No. 177)

Building 885, immediately south of Building 881, is currently used for satellite collection and 90-day accumulation of RCRA regulated wastes. The building will be closed under RCRA Interim Status (40 CFR 265). Complete information on this solid waste management unit is provided in the RCRA Interim Status Closure Plan which is appended to the revised Post-Closure Care Permit Application for hazardous and radioactive mixed wastes at the Rocky Flats Plant (Rockwell International, 1988c). Any ground-water contamination from this site will be addressed by the remedial action for Operable Unit No. 1.

2.0 PHASE I AND PHASE II SITE EVALUATION

2.1 881 HILLSIDE AREA PREVIOUS INVESTIGATIONS

Remedial investigations were performed in two phases at the 881 Hillside Area. The first phase of investigations began in March 1987, in accordance with the plans presented in U. S. DOE (1987a and 1987b). The second phase of field work was performed subsequent to submittal of the draft 881 Hillside Area Phase I RI Report and meetings with CDH and EPA to plan further work based on Phase I results.

Objectives of the remedial investigations were to:

- Verify waste source locations;
- Characterize waste sources;
- Characterize site geology and hydrology;
- Determine the presence and extent of ground-water, surface water, and soil contamination;
- Provide data to estimate the potential for contaminant migration via the ground-water, surface water, and air pathways; and
- Support feasibility studies of alternative remedial actions.

The Phase I and Phase II field programs consisted of:

- Preparation of detailed topographic site maps;
- Radiometric and organic vapor screening surveys;
- Geophysical surveys using electromagnetometry, resistivity, magnetometry, and metal detection;
- Soil gas sampling using the Petrex method;
- Drilling, sampling, and chemical analyses of subsurface soils from 17 Phase I boreholes and 6 Phase II boreholes (Figure 2-1);
- Installation of 4 alluvial wells and 3 bedrock wells during Phase I drilling and 11 alluvial wells and 1 bedrock well during Phase II drilling (Figure 2-1);
- Packer testing of cored bedrock wells;
- Slug testing on all new wells containing sufficient water for testing;
- Single hole pumping tests of wells 2-87 and 4-87;

- Sampling and analysis of ground water from all 1986 wells (up to five quarters of data) and 1987 wells (in general, two samples for Phase I wells and one sample for Phase II wells) in the study area in addition to older wells which had shown contamination in the past;
- Surface water sampling and analysis from stations along Woman Creek and the South Interceptor Ditch, as well as from seeps and springs located in the area; and
- Bedload sediment sampling and analysis in Woman Creek.

In addition to the RI activities at the 881 Hillside Area, several monitor wells were installed as part of a Plant-wide hydrogeologic investigation in 1986 (Rockwell International, 1986e). Surface water, soil, and air samples have also been collected at these areas as part of various investigations; ground-water sampling has been conducted in the area on a quarterly basis since the Phase II RI; and surface water sampling was conducted monthly in 1989. Section 2.2 presents results of the previous RIs and a brief characterization of each contaminant migration pathway at the 881 Hillside Area. The nature and extent of contamination associated with these pathways is discussed in Section 2.3. Section 3.0 discusses the need for and objectives of the Phase III RI.

2.2 SITE CONCEPTUAL MODEL

A site-specific conceptual model of the 881 Hillside Area has been developed based on previous investigations. This model describes contaminant sources and pathways through which contaminant transport may occur from these areas.

2.2.1 Geology

2.2.1.1 Surficial Geology

Surficial materials at the 881 Hillside Area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill unconformably overlying bedrock. In addition, there are a few isolated exposures of claystone bedrock. Figure 2-2 presents the distribution of surficial materials. The study area is located on the south-facing hillside which slopes down from the Rocky Flats terrace toward Woman Creek on the south side of the Plant. Rocky Flats Alluvium caps the top of the slope, and colluvium covers the hillside. Artificial fill and disturbed surficial materials are present around Building 881 and south of the building to the South Interceptor Ditch. Artificial fill overlies colluvium at SWMU 130, and surficial materials are disturbed in the vicinity of SWMUs 119.1 and 119.2. Valley fill alluvium is present along the drainage of Woman Creek south of the 881 Hillside Area, and terrace alluvium occurs on the north side of the Woman Creek valley fill alluvium.

Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at the Rocky Flats Plant (Scott, 1965). The Rocky Flats Alluvium is a series of coalescing alluvial fans deposited by braided streams (Hurr, 1976). The erosional surface (pediment) on which the alluvium was deposited slopes gently eastward truncating the Fox Hills Sandstone, the Laramie Formation, and the Arapahoe Formation at the Rocky Flats Plant.

After deposition of the Rocky Flats Alluvium, eastward flowing streams began dissecting the deposit by headward erosion and lateral planation. All of the alluvium was removed by erosion in the Woman Creek drainage south of the 881 Hillside Area and in the South Walnut Creek drainage to the north. The result is a terrace of Rocky Flats Alluvium extending eastward from the Plant between the two drainages. This terrace forms the crest of the 881 Hillside Area.

Colluvium

Colluvial materials are present on the hillside below the Rocky Flats terrace east of Building 881 and extend south to the Woman Creek drainage (Figure 2-2). These materials are deposited by slope wash and downslope creep of Rocky Flats Alluvium and bedrock. Colluvium ranges from two feet (BH16-87) to twenty-two (well 62-86) feet in thickness.

Colluvial materials on the 881 Hillside have been disturbed by construction of Building 881, various excavation activities associated with the SWMUs, and construction of the South Interceptor Ditch. These areas are shown as disturbed ground on Figure 2-2. Within SWMUs 119.1 and 119.2, shallow excavation took place to construct roadways and to provide level drum storage areas. Colluvium is also disturbed south of Building 881 in the vicinity of SWMUs 106 and 107. This area was excavated during construction of the skimming pond in 1972. Finally, colluvium was excavated along the South Interceptor Ditch during its construction in 1979 to 1981.

Colluvium is undisturbed on the hillside south of SWMUs 130, 119.1, and 119.2. The colluvium is thickest in the north-south trending swales draining the 881 Hillside (wells 4-87 and 6-87) and thinnest over the intervening ridges (wells 48-87, 49-87, and 50-87). Colluvium predominantly consists of clay with common occurrences of sandy clay and gravel layers.

Gravel layers are present in colluvial materials both unconformably overlying bedrock and near the surface. These gravels are likely deposited in a south (downslope) direction by creep and slope wash erosion of the Rocky Flats Alluvium and can be expected to be elongated in the north-south direction with a rather limited extent in the east-west direction. The gravel layers range from 1.3 feet (wells 43-87, 62-86, and 69-86) to 5.5 feet (well 59-86) in thickness. Colluvial gravel deposits can be correlated between some of the wells and boreholes. For example, the basal gravel in well 59-86 can be traced to wells 69-86 and 8-87BR. Sand and gravel layers in well 43-87 can also be correlated with sand and gravel layers in well 4-87.

Terrace Alluvium

A Quaternary terrace alluvium is present on the north side of the Woman Creek valley fill alluvium. This terrace is approximately five to ten feet above the present stream level indicating that it is probably Holocene in age (Scott, 1960). The thickness of the deposit ranges from approximately three (well 58-86) to seven (well 55-87) feet. The terrace alluvium is composed of very poorly sorted gravelly sand.

Valley Fill Alluvium

The most recent alluvial deposit in the 881 Hillside Area is the valley fill alluvium along Woman Creek. This alluvium is derived from reworked and redeposited older alluviums and bedrock. Alluvium thickness ranges from approximately six feet (well 68-86) to nine feet (well 64-86). The unconsolidated valley fill alluvium consists of generally sorted, angular to subrounded granite and quartzite cobbles, pebbles, and gravels in a silty sand matrix.

Artificial Fill

There are two types of artificial fill on the 881 Hillside (Figure 2-2) derived from separate sources. The first is fill material derived from excavation of the Building 881 foundation, and the second is soil placed at SWMU 130 (Section 1.4.8).

Material excavated for the Building 881 foundation was spread over a large area generally south of the building. The very poorly sorted and unconsolidated artificial fill was derived from Rocky Flat Alluvium, colluvium, and claystone bedrock. It is predominantly composed of sandy clay with some gravelly zones.

Soils placed at SWMU 130 comprise the second type of artificial fill. It consists of clayey sand with subangular quartzite cobbles. Asphalt was also encountered from 0 to 2.75 feet in BH11-87. The fill at SWMU 130 overlies natural colluvial materials. In borehole BH11-87, approximately 5 feet of fill are present, with fill thickness increasing to approximately 10 feet in BH10-87. The artificial fill at SWMU 130 was unsaturated during the Phase II RI drilling program.

2.2.1.2 Bedrock Geology

The Cretaceous Arapahoe Formation underlies surficial materials at the 881 Hillside Area. The bedrock beneath the 881 Hillside consists of claystones with interbedded lenticular sandstones, siltstones, and occasional lignite deposits. The bedrock sediments were deposited by meandering streams flowing generally from west to east off the Ancestral Front Range. Sandstones were deposited in stream channels and as overbank splays, and claystones were deposited in back swamp and floodplain areas. Leaf fossils, organic matter, and lignite beds were encountered within the claystones during drilling at the 881 Hillside. Contacts between various lithologies are both gradational and sharp. Based on preliminary results of the ongoing seismic reflection program at Rocky Flats Plant, bedrock is dipping less than two degrees to the east.

Claystones

Arapahoe Formation claystone was the most frequently encountered lithology immediately below the alluvium/bedrock contact. Claystones are generally thinly bedded and contain occasional laminae and interbeds of fine-grained sand and silt (wells 3-87BR, 45-87BR, and 47-87). Intervals of carbonaceous material and fossils (mainly plant fragments and leaves) are also common in the claystones.

Weathered bedrock was encountered directly beneath surficial materials in all of the boreholes and wells, and weathering appears to penetrate between approximately two (borehole BH16-87) and 60 feet (well 62-86BR) into bedrock. The weathered zone is generally consolidated and exhibits blocky structure. Iron oxide staining and concretions along with caliche are characteristic of the zone. The weathered claystone is also characterized by mild fracturing and thus higher hydraulic conductivities than unweathered claystone. In well 5-87BR and abandoned hole 7-87BRA, claystone was mildly fractured from the alluvium/bedrock contact to depths of approximately 46 and 26 feet, respectively. A 45 degree fracture was also identified in weathered claystone in well 8-87BR at a depth of approximately 54 feet. Based on packer tests in wells 5-87BR and 8-87BR, weathered claystones beneath the 881 Hillside have a geometric mean hydraulic conductivity of 7×10^{-7} centimeters per second (cm/s) or 0.7 feet per year (ft/yr).

Unweathered bedrock occurs between 37.7 (well 8-87BR) and 56 feet (well 3-87BR) below ground surface. The unweathered claystones are typically darker gray than weathered claystone and have little mottling. They are also more consolidated than weathered claystones and exhibit little to no fracturing. The geometric mean hydraulic conductivity of unweathered claystones beneath the 881 Hillside is 1×10^{-7} cm/s, based on packer tests in wells 3-87BR, 8-87BR, and 45-87BR.

Sandstones

Arapahoe Formation sandstones were encountered beneath the 881 Hillside in holes 59-86, 62-86, 3-87BR, 5-87BR, 6-87A, 7-87BRA, 8-87BR, and 45-87BR. These sandstones are generally composed of well sorted, subrounded to rounded, very fine- to medium-grained, poorly to moderately well cemented quartz sand with up to 10% lithic fragments. The thickness of individual sandstone beds ranged from approximately five feet (well 5-87BR) to twelve feet (well 8-87BR). The sandstone in well 45-87BR (89.5 - 100.8 feet below ground surface) was described as homogeneous; however, it is generally thinly bedded and often contain laminae and interbeds of clay and silt (up to 2 inches thick in well 45-87BR).

Sandstones encountered in holes 5-87BR, 6-87A, 7-87BRA, and 8-87BR are weathered. Weathered sandstones ranged from olive gray to moderate yellowish brown in color with brown, orange, and yellow iron oxide staining. Weathered sandstones were described as being friable and brittle. Unweathered sandstones are lithologically similar to the weathered sandstones and were found in wells 45-87BR and 3-87BR, at 89.5 feet and 103 feet, respectively. Unweathered sandstones are generally medium dark gray to pale olive in color with infrequent staining of brown and yellows. The deeper unweathered sandstones are generally more consolidated than unweathered sandstone. The orientation, geometry, and extent of bedrock sandstones at the 881 Hillside are not well defined at this time. A seismic reflection program is currently ongoing at the Plant to better characterize bedrock stratigraphy.

A saturated lignite bed was encountered from approximately 85 to 88 feet below ground surface in well 8-87BR and between approximately 87.8 to 88.1 feet below ground surface in well 3-87BR. Very carbonaceous-rich claystones occur frequently in this stratigraphic horizon. Based on the 1.5 to 2.0 degree dip of the bedrock, the two lignite layers correlate and are presumably continuous.

2.2.2 Hydrogeology

Unconfined ground-water flow occurs in surficial materials and subcropping sandstones. In addition, subcropping claystone may be saturated in some locations. Confined ground-water flow occurs in deeper sandstone units.

2.2.2.1 Unconfined Flow System

Ground water is present in the Rocky Flats Alluvium, colluvium, valley fill alluvium, and subcropping sandstones under unconfined conditions. Recharge to the water table occurs as infiltration of incident precipitation and as seepage from ditches and creeks. In addition, retention ponds along Woman Creek likely recharge the valley fill alluvium.

The shallow ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and stream and ditch flow. Alluvial water levels are highest during the spring and early summer months of May and June. Water levels decline during late summer and fall, and some wells go dry at this time of year.

Ground-Water Flow Directions

Figures 2-3, 2-4, 2-5, and 2-6 depict potentiometric conditions in surficial materials in January, May, August, and November 1988, respectively. Ground water flows from the Rocky Flats Alluvium at the top of the 881 Hillside generally southeast through colluvial materials toward Woman Creek. At the Rocky Flats pediment edges, ground water emerges as seeps and springs at the contact between the alluvium and claystone bedrock (contact seeps), is consumed by evapotranspiration, or flows through colluvial materials following topography toward the valley fill and terrace alluviums. Flow through colluvial materials appears to primarily occur in the gravel within the colluvium. Available water level data for well 47-87 indicate that ground water is below the base of the South Interceptor Ditch, although there could be discharge to the ditch during wet periods. Once ground water reaches the valley, it either flows down-valley in the alluvium (easterly), is consumed by evapotranspiration, or discharges to Woman Creek. During the driest portions of the year, evapotranspiration can result in no flow in either the colluvium or the valley fill alluvium.

Ground-Water Flow Rates

Hydraulic conductivity values were developed for surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site characterization (Rockwell International, 1986e) and from bail-down/recovery and single well pumping tests performed on select 1986 and 1987 wells during remedial investigations (Rockwell International, 1987a, 1988a, and 1989a).

Hydraulic conductivity values are available for three wells completed in colluvium at the 881 Hillside; two are completed in gravel layers (wells 69-86 and 4-87) and one is completed in sandy clay (well 2-87). The test results indicate hydraulic conductivities of 9×10^{-4} cm/s and 7×10^{-5} cm/s for the gravel layers and 4×10^{-5} cm/s for the sandy clay. Using the maximum hydraulic conductivity value of 9×10^{-4} cm/s, a gradient of 0.15 for colluvial materials at the hillside, and an assumed effective porosity of 0.1, the maximum possible ground-water velocity through colluvial materials is approximately 1,400 ft/yr. Using the geometric mean hydraulic conductivity of 1×10^{-4} cm/s, a gradient of 0.15, and an effective porosity of 0.1, the mean ground-water velocity through colluvium is approximately 150 ft/yr. Another estimate of colluvial ground-water flow velocity is the downgradient extent of contaminants from SWMUs 119.1 and 130. Based on chemical data presented in Section 2.3, it appears that volatile organics have not yet reached well 47-87 due to unsaturated conditions in the area. Thus, ground water from SWMU 119.1 has moved approximately 200 feet in 15 to 18 years (11 to 13 ft/yr).

Once ground water reaches the creek drainage, it travels within the alluvium east toward the property boundary at Indiana Street. Flow in the alluvium occurs in response to infiltration events, and the saturated thickness decreases following the event by down-valley flow and evapotranspiration. High evaporative losses have been noted repeatedly in investigations of the valley fill alluvium. Hurr (1976) notes that as much as 0.25 cubic feet per second were lost to evapotranspiration along Woman Creek during the period July to September, 1974. In addition, both Rockwell International (1987c) and the DOE (1980) comment on evapotranspirative losses from the valley fill alluvium, based on water level records. Six of the nine wells completed in the Woman Creek alluvium have been dry during at least some portion of the year since their installation. The Phase II RI report (Rockwell International, 1988a) presents water level data which show that the valley fill alluvium is dry at wells 1-86, 64-86, and 66-86 from about June to October (3 months).

Based on evaluation of slug and drawdown/recovery tests, the Woman Creek valley fill alluvium has a geometric mean hydraulic conductivity of 1.5×10^{-3} cm/s (1,035 ft/yr) and a maximum conductivity of 3×10^{-3} cm/s (3,100 ft/yr). A hydraulic gradient of 0.021 was estimated from the grade of the alluvium base (also equal to the topographic gradient), and an assumed effective porosity of 0.1 was used to calculate flow velocity. The resulting ground water flow velocity ranges from 220 to 650 ft/yr using the geometric mean and maximum hydraulic conductivity values.

The assumption that the ground water flows only three quarters of the year is based on water level data from wells completed in Woman Creek alluvium. Because the alluvium is not saturated for the full year, a dissolved particle travels only a portion of this distance each year. Thus, a dissolved particle would travel approximately 160 to 490 feet in valley fill alluvium during a year using the average and maximum hydraulic conductivity values. This maximum possible velocity of 490 ft/yr is based on one test result; other tests in the same material indicate lower velocities. Therefore, the average computed velocity is considered more representative of actual conditions throughout the Woman Creek valley fill. Section 5.0 discusses additional hydraulic testing to estimate hydraulic conductivities as well as dispersion coefficients.

2.2.2.2 Confined Ground-Water Flow System

The greatest potential for ground-water flow in the Arapahoe Formation occurs in the sandstones contained within the claystones. Ground-water recharge to sandstones occurs as infiltration from alluvial ground water where sandstones subcrop beneath the alluvium and by leakage from claystones overlying the sandstones.

Following Robson et al. (1981a), flow within individual sandstones is assumed to be from west to east, but the geometry of the bedrock ground-water flow path is not fully understood at this time due to its dependence upon the continuity of the sandstones and their hydraulic interconnection. Evaluation of the lateral extent and degree of interconnection of the sandstone units is a primary goal of an ongoing program of profiling the Arapahoe Formation through seismic reflection studies.

Hydraulic conductivity values for sandstones were estimated from drawdown-recovery tests performed in 1986, slug tests performed in 1987, and packer tests performed in 1986 and 1987 (Rockwell International, 1988a). Based on drawdown-recovery tests of wells 59-86, 62-86, 3-87, and 5-87, the hydraulic conductivity of sandstone ranges from 2×10^{-6} cm/s to 2×10^{-4} cm/s with a geometric mean of 3×10^{-5} cm/s. The wide variation of results for a similar geologic material is reasonable given the variable silt content of the sandstones.

2.2.3 Surface Water Hydrology

2.2.3.1 Woman Creek

Woman Creek is located south of the 881 Hillside Area with its headwaters in largely undisturbed Rocky Flats Alluvium. Runoff from the southern part of the Plant is collected in the South Interceptor Ditch located due north of the creek and delivered to Pond C-2. Pond C-1 (upstream of C-2) receives stream flow from Woman Creek. The discharge from Pond C-1 is diverted around Pond C-2 into the Woman Creek channel downstream. Water in Pond C-2 is discharged to Woman Creek in accordance with the Plant NPDES permit (discharge point 007).

Flow in Woman Creek and the South Interceptor Ditch is intermittent, appearing and disappearing along various reaches. During the 1986 initial site characterization, measurable flow occurred at less than one-half of the ten stations located along Woman Creek and the South Interceptor Ditch (Rockwell International, 1986e). All recorded flows were less than ten gallons per minute. During the 1986 and 1987 investigations, there was no surface flow in Woman Creek downstream of Pond C-2. The intermittent surface water flow observed for Woman Creek and the South Interceptor Ditch is indicative of frequent interaction with the shallow ground-water system.

2.3 NATURE AND EXTENT OF CONTAMINATION

2.3.1 Background Characterization

In order to facilitate the interpretation of chemical results in non-background areas, a background characterization program has been implemented to define the spatial and temporal variability of naturally occurring constituents. A plan was completed in January 1989 (Rockwell International, 1989b), field work was conducted, and a draft Background Geochemical Characterization Report was prepared and submitted to the regulatory agencies in December 1989 (Rockwell International, 1989c). The document summarizes the background data for ground water, surface water, sediments, and geologic materials, and identifies preliminary statistical boundaries of background variability. Spatial variations in the chemistry of geologic materials and water were addressed by placing sample locations throughout background areas at the Plant. The goal of evaluating temporal variations in water chemistry has not yet been achieved because at least two years of quarterly data are needed. The draft report will be updated in 1990 by incorporation of additional analytical data, including a second round of ground-water samples for which laboratory analyses were not available in December 1989. The information in the draft background geochemical report has been used to preliminarily characterize inorganic contamination at the 881 Hillside Area.

The boundaries of background variability were quantified through the calculation of tolerance intervals assuming a normal distribution. Assumptions and statistical analyses of the background tolerance intervals are presented in Rockwell International (1989c). The upper limit of the tolerance interval or the maximum detected value for each parameter analyzed in background ground-water, surface water, sediment, and geologic samples are provided in Tables 2-1 through 2-4, respectively. Maximum detected values are provided where there were insufficient data to calculate tolerance intervals. This condition resulted from either an insufficient number of samples, or an insufficient number of detectable concentrations for a given analyte. Background samples were not analyzed for EPA Contract Laboratory Program (CLP) Target Compound List (TCL) organics, because the background areas are outside of potentially contaminated areas.

To assess the presence of inorganic contamination at the 881 Hillside Area, site-specific chemical data are compared to the background tolerance intervals or the maximum detected value if a tolerance interval could not be calculated. A constituent concentration that is greater than the upper limit of the one-sided 95% tolerance interval at the 95% confidence level will be considered to preliminarily represent contamination. Although not necessarily statistically significant, site specific chemical concentrations above the maximum detected background value will also be preliminarily considered to represent contamination.

TABLE 2-1

BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Dissolved Metals							
Aluminum	mg/l	ND	ND	ND	ND	ND	0.327*
Antimony	mg/l	ND	ND	ND	ND	ND	ND
Arsenic	mg/l	ND	ND	ND	ND	ND	0.0186*
Barium	mg/l	ND	ND	ND	ND	ND	ND
Beryllium	mg/l	ND	ND	ND	ND	ND	ND
Cadmium	mg/l	ND	ND	ND	ND	ND	ND
Calcium	mg/l	85	76.8*	138	73.4*	65.7*	64.6
Cesium	mg/l	ND	ND	ND	ND	ND	ND
Chromium	mg/l	ND	ND	ND	ND	0.0122*	ND
Cobalt	mg/l	ND	ND	ND	ND	ND	ND
Copper	mg/l	ND	ND	ND	ND	ND	ND
Iron	mg/l	0.266*	ND	0.94*	ND	ND	ND
Lead	mg/l	ND	ND	ND	ND	ND	ND
Lithium	mg/l	ND	0.172*	0.028	.031*	0.0106*	ND
Magnesium	mg/l	5.79*	15.3*	26.57	45.3*	9.41*	ND
Manganese	mg/l	0.365	0.088*	0.686*	0.126*	0.292*	0.0182*
Mercury	mg/l	ND	ND	0.003*	.008*	ND	ND
Molybdenum	mg/l	0.0136*	ND	ND	0.015*	0.015*	0.112*
Nickel	mg/l	0.0432*	ND	ND	ND	ND	ND
Potassium	mg/l	7.73*	ND	ND	ND	ND	21.89*
Selenium	mg/l	ND	ND	0.0114*	ND	ND	0.041*
Silver	mg/l	ND	ND	ND	ND	ND	ND
Sodium	mg/l	13.4	98.7*	88	36.9*	25.6*	599
Strontium	mg/l	0.159*	ND	ND	ND	ND	0.451*
Thallium	mg/l	ND	ND	ND	0.01*	ND	ND
Tin	mg/l	ND	ND	ND	ND	ND	
Vanadium	mg/l	ND	ND	ND	ND	ND	ND
Zinc	mg/l	0.141*	ND	0.0212*	0.107*	ND	0.564

eg&g\881\ri-fs\tbl-2-1.881

TABLE 2-1 (cont.)

BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Other							
Total Dissolved Solids	mg/l	352	520*	947	320*	170*	1761
Carbonate	mg/l	ND	ND	ND	ND	ND	49
Bicarbonate	mg/l	436	470*	719	400*	140*	412
Chloride	mg/l	15.6	20*	40.29	11*	15*	607
Sulfate	mg/l	45.1	86*	150	44*	16*	950
Nitrate	mg/l	2.98	0.18*	0.69*	0.58*	1.6*	0.610
Cyanide	mg/l	.0038*	ND	ND	0.0036*	ND	ND
pH	----	8.6 (5.98)	7.4* (7.1)**	8.68 (6.12)	8.2* (7.4)**	7.5* (7.2)**	10.57 (7.43)
Dissolved Radionuclides							
Gross Alpha	pCi/l	12.543	27*	13.515	12*	7*	13*
Gross Beta	pCi/l	14.570	12*	18.530	7*	2*	15*
Uranium 233, 234	pCi/l	1.647	11*	6.481	5.8*	1.1*	12.936
Uranium 235	pCi/l	0.000	0.3*	0.232	0.2*	0*	0.135
Uranium 238	pCi/l	0.195	7.7*	5.084	3.2	0.6*	3.3507
Strontium 89, 90	pCi/l	0.552	0.1*	0.878	0.1	-0.1*	0.2*
Plutonium 239, 240	pCi/l	0.009	0*	0.012	0.03	0.01*	0.000
Americium 241	pCi/l	0.000	0*	0.012	0	0.01*	0.019
Cesium 137	pCi/l	0.603	0.2*	0.776	0.4	0.3*	0.7*
Tritium	pCi/l	309	100*	505	100	100*	731

* - Maximum Detected Value
** - Minimum Detected Value
ND - Not Detected at Contract Required Detection Limit
() - Tolerance Interval Lower Limit for Two-Sided Parameter

eg&g\881\ri-fs\tbl-2-1.881

TABLE 2-2

BACKGROUND SURFACE WATER (ROUNDS 1 and 2)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Round 1 (9 samples) Total	Round 1 (9 samples) Dissolved	Round 2 (7 samples) Total	Round 2 (7 samples) Dissolved
Metals					
Aluminum	mg/l	64.10*	0.485*	8.444	0.454*
Antimony	mg/l	ND	ND	ND	ND
Arsenic	mg/l	0.116*	ND	0.294*	ND
Barium	mg/l	4.49*	ND	ND	ND
Beryllium	mg/l	0.0097*	ND	ND	ND
Cadmium	mg/l	0.0690*	ND	ND	ND
Calcium	mg/l	254.11	99.14	105.03	93.27
Cesium	mg/l	2.53*	ND	ND	ND
Chromium	mg/l	0.0598*	ND	0.0115*	ND
Cobalt	mg/l	0.0730*	ND	ND	ND
Copper	mg/l	0.180*	ND	ND	ND
Iron	mg/l	692.59	4.69*	12.070	0.453*
Lead	mg/l	0.233*	0.0055*	0.0308*	0.0131*
Lithium	mg/l	ND	ND	0.0192*	0.0166*
Magnesium	mg/l	27.71	11.98	17.578	15.74
Manganese	mg/l	1.140	0.826	1.101	0.232
Mercury	mg/l	0.001	0.002	0.004*	0.0004*
Molybdenum	mg/l	0.199*	ND	0.026	0.032
Nickel	mg/l	0.251*	ND	ND	ND
Potassium	mg/l	9.86*	ND	ND	ND
Selenium	mg/l	ND	ND	ND	ND
Silver	mg/l	0.148*	0.0125*	ND	ND
Sodium	mg/l	43.020	44.81	42.651	43.22
Strontium	mg/l	1.341	0.35	ND	ND
Thallium	mg/l	ND	ND	ND	ND
Tin	mg/l	0.969*	ND	ND	ND
Vanadium	mg/l	0.364*	ND	ND	ND
Zinc	mg/l	0.723*	.032	0.0892*	0.0228*

TABLE 2-2 (cont.)

BACKGROUND SURFACE WATER (ROUNDS 1 and 2)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Round 1 (9 samples) Total	Round 1 Dissolved	Round 2 (7 samples) Total	Round 2 Dissolved
Other					
Total Dissolved Solids	mg/l	329.52	NA	365.15	NA
Carbonate	mg/l	ND	NA	ND	NA
Bicarbonate	mg/l	389.72	NA	344.21	NA
Chloride	mg/l	89.11	NA	82.56	NA
Sulfate	mg/l	50.20	NA	65.30	NA
Nitrate	mg/l	2.45	NA	2.1*	NA
Cyanide	mg/l	ND	NA	0.0043*	NA
pH	----	9.02 (5.89)	NA	8.3 (6.44)	NA
Radionuclides					
Gross Alpha	pCi/l	266	5.805	106	NA
Gross Beta	pCi/l	213	9.335	79	NA
Uranium 233, 234	pCi/l	1.250	3.684	1.326	NA
Uranium 235	pCi/l	0.106	0.364	0.000	NA
Uranium 238	pCi/l	0.937	2.311	0.977	NA
Strontium 89, 90	pCi/l	2.160	1.452	1.243	NA
Plutonium 239, 240	pCi/l	1.066	0.017	0.112	NA
Americium 241	pCi/l	0.111	0.014	0.014	NA
Cesium 137	pCi/l	12.788	0.591	1.059	NA
Tritium	pCi/l	266	NA	863	NA

NA - Not Analyzed
ND - Not Detected
* - Maximum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

TABLE 2-3

BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
<u>Total Metals</u>		
Aluminum	mg/l	24789
Antimony	mg/l	ND
Arsenic	mg/l	13.0*
Barium	mg/l	182*
Beryllium	mg/l	ND
Cadmium	mg/l	ND
Calcium	mg/l	72551
Cesium	mg/l	ND
Chromium	mg/l	43.38
Cobalt	mg/l	ND
Copper	mg/l	22.0*
Iron	mg/l	28308
Lead	mg/l	39.502
Lithium	mg/l	ND
Magnesium	mg/l	4110*
Manganese	mg/l	372.20
Mercury	mg/l	ND
Molybdenum	mg/l	ND
Nickel	mg/l	29.9*
Potassium	mg/l	ND
Selenium	mg/l	ND
Silver	mg/l	6.8*
Sodium	mg/l	ND
Strontium	mg/l	175*
Thallium	mg/l	ND
Tin	mg/l	ND
Vanadium	mg/l	50.2*
Zinc	mg/l	92.688

TABLE 2-3 (cont.)

BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
<u>Other</u>		
Nitrate	mg/l	ND
pH	----	9.03 (8.77)
<u>Total Radionuclides</u>		
Gross Alpha	pCi/l	60
Gross Beta	pCi/l	50
Uranium 233, 234	pCi/l	1.669
Uranium 235	pCi/l	0.176
Uranium 238	pCi/l	1.755
Strontium 89, 90	pCi/l	1.390
Plutonium 239, 240	pCi/l	0.096
Americium 241	pCi/l	0.029
Cesium 137	pCi/l	1.578
Tritium	pCi/l	0.408

ND - Not Detected
* - Maximum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

eg&g\881\ri-fs\tbl-2-3.881

TABLE 2-4

**BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE**

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
Total Metals					
Aluminum	mg/l	25312	21663	13495	10300*
Antimony	mg/l	ND	ND	16.2*	ND
Arsenic	mg/l	15.86	7.7	15.05	3.6*
Barium	mg/l	155.8	345.8	240.1	165*
Beryllium	mg/l	11.27	17.75	11.8	2.2*
Cadmium	mg/l	3.2*	1.8*	ND	ND
Calcium	mg/l	43079	20811	10183	5940*
Cesium	mg/l	ND	274*	ND	ND
Chromium	mg/l	37.9	26.8	16.57	10.7*
Cobalt	mg/l	18.2*	15.9*	29.7*	20.5*
Copper	mg/l	20.03	26.7	30.62	19.6*
Iron	mg/l	22916	29991	41295	12300*
Lead	mg/l	18.04	26.4	34.5	13.4*
Lithium	mg/l	44.4	32.1	33.37	7.0*
Magnesium	mg/l	4425	6151	4896	2520*
Manganese	mg/l	422.9	545.1	656	305*
Mercury	mg/l	0.58*	0.44*	0.35*	0.27*
Molybdenum	mg/l	38.65	32.78	33.68	11.2*
Nickel	mg/l	43.27	35.4	56.95	14.3*
Potassium	mg/l	3336	2789	1400*	ND
Selenium	mg/l	ND	ND	ND	ND
Silver	mg/l	40.9*	33.5*	18.7*	12.7*
Sodium	mg/l	ND	3680*	ND	ND
Strontium	mg/l	226*	111.1	144.42	69.2*
Thallium	mg/l	ND	ND	ND	ND
Tin	mg/l	338*	441*	274*	268*
Vanadium	mg/l	54.67	58.2	47.7	22.2*
Zinc	mg/l	52.64	98.1	106.7	79.9*

TABLE 2-4 (cont.)

BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
Other					
Sulfide	mg/l	13*	5*	5*	2*
Nitrate	mg/l	4.3*	4.274	2.0*	1.9*
pH	----	9.64 (6.06)	9.48 (6.96)	10.14 (7.04)	9.2* (8.0)**
Total Radionuclides					
Gross Alpha	pCi/l	37.108	51.710	52.302	37
Gross Beta	pCi/l	36.886	35.135	35.743	29
Uranium 233, 234	pCi/l	1.491	1.759	1.985	0.8
Uranium 235	pCi/l	0.087	0.169	0.258	0.1
Uranium 238	pCi/l	1.353	1.675	1.643	1.0
Strontium 89, 90	pCi/l	0.768	0.776	0.786	0.4
Plutonium 239, 240	pCi/l	0.017	0.023	0.020	0.01
Americium 241	pCi/l	0.018	NR	NR	NR
Cesium 137	pCi/l	0.082	0.113	ND	0.0
Tritium	pCi/l	0.410	0.299	0.322	0.39

ND - Not Detected
NR - Data Not Received
* - Maximum Detected Value
** - Minimum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

2.3.2 Soils

Phase I and II of the RI for Operable Unit No. 1 focused on source characterization of preliminarily identified past waste disposal sites. Soil samples were collected from Rocky Flats Alluvium, colluvium and weathered claystone in 1987 in order to characterize the SWMUs. These soil samples were analyzed for the parameters listed in Table 2-5. Table 2-6 lists 881 Hillside borehole sampling information including sample depths, material sampled, and target SWMUs. Figure 2-1 shows Phase I and II RI borehole sampling locations.

2.3.2.1 Organics

Volatile organics data for soils previously collected from the 881 Hillside Area have been rejected during the data validation process for not meeting quality control specifications. Although these data cannot be used to quantitatively determine the extent of volatile organics contamination in this area, they are summarized here because they provide a qualitative indication of the spatial distribution of organic contamination in the soils and the relative magnitude of the contamination.

Methylene chloride, acetone, and phthalates were generally ubiquitous contaminants in the 881 Hillside soil samples. There has been considerable debate as to whether they are truly contaminants of the soils. Methylene chloride and acetone may be laboratory contaminants because of the relatively high levels in many of the laboratory blanks, exacerbated by use of an inappropriately small sample aliquot for soil analysis. It is believed that the phthalate contamination may have resulted from sample handling; however, no testing has been performed to verify this hypothesis. Although the absence of methylene chloride, acetone, and phthalates can not be proven, other evidence that supports this contention is the absence or infrequent occurrence below detection limits (often also occurring in the laboratory blank) of methylene chloride and acetone in ground water (these contaminants are very mobile and soluble), and the presence of phthalates in practically every soil sample (not suggestive of contamination).

TABLE 2-5

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

METALS

Hazardous Substances List - Metals

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

Other Metals

- Chromium (hexavalent)
- Chromium (trivalent)
- Lithium
- Strontium

ORGANICS

Hazardous Substances List -- Volatiles

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- trans-1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene

TABLE 2-5 (CONTINUED)

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List - Volatiles (Continued)

- 2-Chloroethyl Vinyl Ether
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

Hazardous Substances List -- Semi-Volatiles

- N-Nitrosodimethylamine
- Phenol
- Aniline
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphtalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethyl Phthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol

TABLE 2-5 (CONTINUED)

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List -- Semi-Volatiles (Continued)

- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Benzidine
- Pyrene
- Butyl Benzyl Phthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Hazardous Substances List -- Pesticides/PCBS

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endrin Aldehyde
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

Other Organics

- Oil and Grease

TABLE 2-5 (CONTINUED)

PHASE I AND PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+234, 235 and 238
- Americium 241
- Plutonium 239+240
- Strontium 89 + 90
- Cesium 137
- Tritium

OTHER

- pH

TABLE 2-6

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	SWMU No.
BH0187	BH018701WT	06/04/87	0.20 - 1.40	WT	QRF	145
BH0187	BH018704WS	06/04/87	4.50 - 5.70	CT,DH	KACS	
BH0187	BH018710WS	06/04/87	10.00 - 11.50	BR,DH	KACS	
BH0287	BH02870012	05/27/87	0.00 - 11.80	CO,FS	QC	106, 107
BH0287	BH02871214	05/27/87	11.80 - 14.30	CO	QC	
BH0287	BH02871420	05/27/87	14.30 - 20.40	CO	KACS	
BH0287	BH028714CT	05/27/87	12.00 - 14.30	CT	KACS	
BH0287	BH028718BR	05/27/87	17.90 - 18.60	BR	KACS	
BH0387	BH03870009	05/19/87	0.00 - 8.75	CO	QC	130
BH0387	BH03870204	05/19/87	2.00 - 4.00	CO	QC	
BH0387	BH038702WT	05/19/87	2.45 - 3.90	WT	QC	
BH0387	BH038709CT	05/19/87	7.15 - 8.75	CT	QC	
BH0387	BH038712BR	05/19/87	11.75 - 13.25	BR	KACS	
BH0487	BH04870010	06/05/87	0.00 - 10.00	CO	QC	105.1, 105.2
BH0487	BH048710WT	06/05/87	10.30 - 12.80	WT	QC	
BH0487	BH048715CT	06/05/87	15.30 - 15.70	CT	KACS	
BH0487	BH048719BR	06/05/87	19.30 - 20.30	BR	KACS	
BH0587	BH05870005	05/19/87	0.00 - 4.50	CO	QC	103, 107
BH0587	BH058705CT	05/19/87	2.00 - 4.50	CT	QC	
BH0587	BH058708BR	05/19/87	7.50 - 9.30	BR	KACS	
BH0687	BH06870010	05/20/87	0.00 - 10.00	CO	QC	102
BH0687	BH06871020	05/20/87	10.00 - 20.00	CO	QC	
BH0687	BH068726CT	05/20/87	24.10 - 25.50	CT	QC	
BH0687	BH068730BR	05/20/87	27.00 - 30.00	BR	KACS	

Sample Type Codes: BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Unweathered Claystone

TABLE 2-6 (cont.)

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	SWMU No.
BH0787	BH07870510	05/26/87	5.00 - 10.00	CO	KACS	104, 130
BH0787	BH078705CT	05/26/87	4.30 - 4.80	CT,FS	QC	
BH0787	BH078708BR	05/26/87	7.80 - 9.68	BR	KACS	
BH0787	BH07871013	05/26/87	10.35 - 13.00	CO	KACS	
BH0787	BH078710WS	05/26/87	9.68 - 10.35	FS	KACS	
BH0887	BH08870007	06/03/87	0.00 - 6.10	CO	QC	119.1
BH0887	BH088707CT	06/03/87	6.10 - 7.00	CT	QC	
BH0887	BH088710BR	06/03/87	10.20 - 12.10	BR	KACS	
BH0987	BH09870010	05/29/87	0.00 - 10.00	CO	QC	119.1
BH0987	BH098706WT	05/29/87	6.03 - 6.60	WT	QC	
BH0987	BH098711CT	05/29/87	10.08 - 11.30	CT	QC	
BH0987	BH098714BR	05/29/87	14.30 - 14.75	BR	KACS	
BH1087	BH10980010	06/01/87	0.00 - 10.00	CO	QC	130
BH1087	BH10871020	06/01/87	10.00 - 18.95	CO	QC	
BH1087	BH108720CT	06/01/87	18.95 - 20.00	CT	QC	
BH1087	BH108723BR	06/01/87	23.00 - 25.40	BR	KACS	
BH1187	BH11870010	06/02/87	0.00 - 10.00	CO	QC	130
BH1187	BH118711CT	06/02/87	8.70 - 10.70	CT,FS	QC	
BH1187	BH118714WT	06/02/87	13.90 - 17.00	WT,BR	KACS	
BH1287	BH128702CT	05/27/87	0.00 - 2.25	CO	QC	119.1
BH1287	BH128705BR	05/27/87	5.25 - 6.50	BR	KACS	

Sample Type Codes: BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Unweathered Claystone

TABLE 2-6 (cont.)

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	SWMU No.
BH1387	BH13870010	05/29/87	0.00 - 10.10	CO	QC	130
BH1387	BH138711CT	05/29/87	10.10 - 11.56	CT,FS	QC	
BH1387	BH138714BR	05/29/87	14.56 - 16.20	BR	KACS	
BH1487	BH148703W1	05/28/87	2.00 - 2.90	DH	QC	119.1
BH1487	BH148706CT	05/28/87	5.50 - 6.50	CT	QC	
BH1487	BH148708W2	05/28/87	7.75 - 8.00	DH,BR	KACS	
BH1487	BH148709BR	05/28/87	6.50 - 9.00	BR	KACS	
BH1587	BH15870005	06/03/87	0.00 - 5.00	CO	QRF	119.1
BH1587	BH158726BR	06/03/87	24.10 - 25.80	BR	KACS	
BH1687	BH16870206	06/02/87	2.00 - 6.00	CO	KACS	119.2
BH1687	BH168702CT	06/02/87	0.00 - 1.80	CT	QC	
BH1687	BH168706BR	06/02/87	6.00 - 6.50	BR	KACS	
BH1787	BH17870005	06/03/87	0.00 - 3.90	CO	QC	119.2
BH1787	BH178705CT	06/03/87	3.90 - 5.25	CT	QC	
BH1787	BH178708BR	06/03/87	8.25 - 8.70	BR	KACS	
BH5787	BH578704DH	10/07/87	4.00 - 5.80	DH	QC	119.1
BH5787	BH578708DH	10/07/87	8.00 - 10.00	DH	QC	
BH5787	BH578710UC	10/07/87	10.00 - 12.00	UC	QC	
BH5787	BH578712CT	10/07/87	12.00 - 14.00	CT	KACS	
BH5787	BH578714BR	10/08/87	14.00 - 16.00	BR	KACS	
BH5787	BH578716DH	10/08/87	16.00 - 18.00	DH	KACS	

Sample Type Codes: BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Unweathered Claystone

TABLE 2-6 (cont.)

BOREHOLE SAMPLE INFORMATION

881 HILLSIDE BOREHOLES

Borehole Number	SAMPLE INFORMATION Number	Date	Depth Increment (ft)	Sample Type	Material Sampled	SWMU No.
BH5787	BH578718DH	10/08/87	18.00 - 20.00	DH	KACS	119.1
BH5787	BH578720DH	10/08/87	20.00 - 22.00	DH	KACS	
BH5787	BH578722DH	10/08/87	22.00 - 24.00	DH	KACS	
BH5787	BH578724DH	10/08/87	24.00 - 26.00	DH	KACS	
BH5787	BH578726DH	10/08/87	26.00 - 28.00	DH	KACS	
BH5887	BH588700UC	10/08/87	0.00 - 1.70	UC	QC	119.2
BH5887	BH588702CT	10/08/87	2.00 - 3.90	CT	QC	
BH5887	BH588704BR	10/08/87	4.00 - 7.10	BR	KACS	
BH5987	BH598704UC	10/05/87	2.00 - 3.50	UC	QC	119.2
BH5987	BH598707CT	10/05/87	4.00 - 7.00	CT	KACS	
BH5987	BH598709BR	10/05/87	7.00 - 9.80	BR	KACS	
BH6187	BH618707DH	10/12/87	6.50 - 9.00	DH	QC	119.2
BH6187	BH618709CT	10/13/87	9.00 - 11.50	CT	KACS	
BH6187	BH618712BR	10/13/87	11.50 - 14.00	BR	KACS	
BH6287	BH62870008	10/21/87	0.00 - 8.00	COMP	QC	105.1, 105.2
BH6287	BH62870080	10/21/87	0.00 - 8.00	DUP	QC	
BH6287	BH628712CT	10/21/87	12.50 - 14.00	CT	KACS	
BH6287	BH628714BR	10/21/87	14.00 - 16.00	BR	KACS	
BH6387	BH63870008	10/16/87	0.00 - 8.00	COMP	QRF	105.1, 105.2
BH6387	BH638712DH	10/16/87	12.00 - 13.70	DH	QRF	
BH6387	BH638718UC	10/19/87	18.00 - 18.40	UC	QRF	
BH6387	BH638722CT	10/19/87	22.00 - 22.50	CT	KACS	
BH6387	BH638724BR	10/19/87	24.50 - 26.00	BR	KACS	

Sample Type Codes: BR - Bedrock CO - Composite CT - Contact DH - Direct Hit FS - Field Screen WT - Water Table
QRF - Rocky Flats Alluvium QC - Colluvium KACS - Unweathered Claystone

Volatile chlorinated hydrocarbon contamination is apparently not extensive. It occurred in soils from only 3 of the 23 boreholes [(BH01-87 (SWMUs 107 and 177), BH57-87 (SWMU 119.1), and BH58-87 (SWMU 119.2)]. The highest concentrations detected were tetrachloroethene (PCE) at 190 micrograms per kilogram (μg/kg) in BH01-87, trichloroethene (TCE) at 150 μg/kg in BH57-87, and 1,1,1-trichoroethane (1,1,1-TCA) at 110 μg/kg in BH57-87.

Boreholes will be drilled and samples collected from all SWMUs for organic analysis during the Phase III RI. An objective of this program will be to determine whether methylene chloride, acetone, and phthalates are soil contaminants. Other objectives include: verification of SWMU locations; assessment of the vertical and horizontal distribution of organic contamination; and identification of maximum concentrations of contaminants in suspected "hot spots".

2.3.2.2 Metals

In general, metal concentrations in soil samples from Rocky Flats Alluvium, colluvium and claystone were within background levels. Trace metals which occurred above background in these three materials include: antimony (3.4%), arsenic (30.3%), mercury (5.6%), cadmium (60.7%), manganese (1.1%), and barium (6.7%). Parentheses indicate the percent of the samples exceeding the background range. These metal concentrations occurred randomly throughout the 881 Hillside soils, and did not exceed a factor of two of the upper limit of the background tolerance interval or range. These low concentrations of metals above background and their random spatial distribution does not suggest these metals represent contaminants.

2.3.2.3 Radionuclides

Radionuclide concentrations have been compared to the upper limit of the background tolerance interval or background range as appropriate. However, this comparison requires consideration of the following information regarding error terms.

Radionuclides are analyzed by counting sub-atomic particle emissions, which is a random function. Since radioactive disintegration is a statistical process and therefore has a probability distribution, results are reported as a measured value with an associated two standard deviation propagated error term following the measured value. Radionuclide concentrations where the error term is larger than the measured value can be considered not statistically different from background because of the significant overlap of the probability distributions. On the other hand, if the measured value minus the error term for a sample is greater than the measured value plus the error term for the upper limit of the background range, it can be considered statistically different from background.

Table 2-7 presents the percent of samples for each radionuclide detected above background at the surface and in the subsurface. Plutonium and americium were only detected above background in surface soils (maximum concentrations were 0.91 ± 0.38 pCi/g and 0.15 ± 0.13 pCi/g, respectively). The origin of this contamination is likely the 903 Pad Area resulting from wind dissemination of plutonium/americium contaminated dust. Because surface samples are 12 to 24 inch composites, actual near surface concentrations are much higher. More recently collected data for plutonium, uranium 238, and uranium 233 + 234 concentrations in surface scrape samples are presented in Table 2-8 (U. S. DOE, 1990b). Sample locations are shown in Figure 2-7. Plutonium concentrations were as high as 4.8 pCi/g in surface soils at the 881 Hillside Area. These concentrations are typical of surface plutonium concentrations in this vicinity and to the east within the Plant boundary (Rockwell International, 1987b). High uranium concentrations occurred in samples 16 through 19. Depleted uranium which is used at the Rocky Flat Plant has a uranium 233 + 234 to uranium 238 activity ratio of less than one, whereas natural uranium has a ratio greater than one. The uranium isotope ratios for these surface soils indicate the uranium is depleted (low ratio). The contamination presumably resulted from drums that had leaked in the past or from past spills.

TABLE 2-7

PERCENT OF SOIL SAMPLES WITH RADIONUCLIDES ABOVE BACKGROUND

Radionuclide	Percent of Surface Samples Above Background	Percent of Subsurface Samples Above Background
Uranium (Total)	6	6
Plutonium 239 + 240	11	0
Americium 241	6	0
Cesium 137	17	7
Tritium	6	3

TABLE 2-8

881 HILLSIDE 1988 SURFACE SCRAPE SAMPLING RESULTS

RADIONUCLIDE CONCENTRATION IN pCi/g

Sample No.	Uranium 233 + 234	Uranium 238	Plutonium
881-1	0.56±0.26	0.6±0.15	4.3±0.5
881-2	0.78±0.26	0.86±0.15	2.4±0.2
881-3	0.82±0.26	0.91±0.15	4.8±0.5
881-4	1.0±0.3	0.97±0.2	0.18±0.006
881-5	0.86±0.26	0.88±0.15	0.59±0.008
881-6	1.5±0.3	5.5±0.5	2.2±0.2
881-7	0.74±0.26	0.75±0.15	0.63±0.09
881-8	0.86±0.26	0.82±0.15	1.8±0.2
881-9	3.1±0.3	1.0±0.2	0.47±0.006
881-10	1.1±0.3	0.98±0.2	3.5±0.4
881-11	1.0±0.3	1.3±0.2	2.6±0.3
881-12	0.93±0.26	1.4±0.2	0.4±0.06
881-13	0.94±0.26	1.3±0.2	0.16±0.06
881-14	1.1±0.3	1.0±0.2	3.0±0.4
881-15	2.0±0.3	1.5±0.16	0.01±0.06
881-16	50±190	1300±100	0.3±0.06
881-17	19±74	590±70	0.78±0.19
881-18	60±230	3000±300	0.42±0.08
881-19	10±740	550±60	0.09±0.06

Data from: U. S. DOE, 1990b

Referring again to Table 2-7, uranium, cesium, and tritium occur infrequently above background and occur at depth (Appendix A). None of these radionuclides were present above background by more than a factor of two above the upper tolerance interval. The uranium 233 + 234 to uranium 238 activity ratios are greater than one indicating the uranium is natural. A DOE news release dated August 11, 1989 stated that a DOE safety assessment team found no evidence of a criticality at the Rocky Flats Plant. Therefore, the cesium 137 is presumed to be due to fallout. This suggests that these radionuclide concentrations may represent natural variations outside the background tolerance intervals.

2.3.3 Ground Water

Ground water at the 881 Hillside occurs in alluvium, colluvium, valley fill alluvium, and weathered and unweathered bedrock. The discussion of ground-water quality is subdivided by SWMU groupings. Ground water at or downgradient of SWMUs 102, 103, 105, 106, 107, 145, and 177 is discussed first. These SWMUs are in close proximity to each other. A discussion of ground water at or downgradient of SWMUs 119.1, 119.2 and 130 follows.

Within each SWMU grouping, the discussion of chemistry has been subdivided into ground water in surficial material (Rocky Flats Alluvium, colluvium and valley fill alluvium) and weathered bedrock (unconfined flow system), and ground water in unweathered bedrock (confined flow system). The most significant contamination exists in surficial materials; however, weathered bedrock ground water is hydraulically connected to surficial materials.

Ground-water samples were analyzed for the parameters listed in Table 2-9. With respect to volatile organics, the discussion is based on the most recent data from the second quarter of 1989 (Appendix B). With respect to inorganic chemistry, first quarter 1988 site data are compared to the appropriate tolerance intervals for background ground-water quality (Appendix B). First quarter 1988 data were chosen because they are the most recent data pertaining to the same season for which the background ground-water tolerance intervals were

TABLE 2-9

PHASE I AND PHASE II RI
GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen*

INDICATORS

- Total Dissolved Solids
- Total Suspended Solids*

METALS**

- Hazardous Substances List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Tin
  - Vanadium
  - Zinc
- Other Metals
  - Chromium (hexavalent)
  - Lithium
  - Strontium

ANIONS

- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate

ORGANICS

- Oil and Grease
- Hazardous Substances List - Volatiles***
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane

TABLE 2-9 (CONTINUED)

PHASE I AND PHASE II RI
GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

ORGANICS

Hazardous Substances List - Volatiles*** (Continued)

- trans-1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- 2-Chloroethyl Vinyl Ether
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+234, 235, and 238
- Americium 241
- Plutonium 239+240
- Strontium 90
- Cesium 137
- Tritium

* For surface water samples only
** Dissolved metals for ground-water samples, total and dissolved metals for surface water samples
*** Ground-water samples from the first quarter of 1987, and all surface water samples were analyzed for 9 of the HSL volatiles. These volatiles are the chlorinated solvents historically detected in the ground water and are as follows: PCE, TCE, 1,1-DCE, 1,2-DCA, t-1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, CCl_4 and $CHCl_3$.

calculated. Data from other quarters generally support conclusions drawn here. Organic data and inorganic data where concentrations exceed the background range are presented in Appendix B.

2.3.3.1 SWMUs 102, 103, 105, 107, and 145

Ground Water in Surficial Materials

Ten monitor wells have been completed in surficial materials in the vicinity or downgradient of SWMUs 102, 103, 105, 106, 107, and 145. These wells are 1-87, 51-87, 52-87, 58-86, 68-86, 69-86, 2-87, 53-87, 54-87, and 59-86. With the exception of wells 2-87, 52-87, and 69-89, these wells were either dry or contained insufficient water for chemical analysis during first quarter 1988. Although wells 1-87 and 68-86 are upgradient of these SWMUs, ground-water quality in these wells is occasionally above background with respect to certain major ions, trace metals and organics as discussed below. Ground-water quality in these wells may be affected by Plant activities upgradient of 881 Hillside, and additional upgradient wells will be installed to investigate this possibility.

Of the wells downgradient from these SWMUs, organics were not detected during the second quarter 1989; however, it is noted that wells 52-87 and 2-87 had detectable volatile organics during first quarter 1989 (Table 2-10). PCE was estimated below detection limits in both wells at concentrations of 2J micrograms per liter (μg/l) and 35J μg/l, respectively. TCE was also estimated below detection limits in well 2-87 at a concentration of 2J μg/l. With the exception of well 69-86, the remaining wells were dry during first quarter and second quarter 1989.

Ground-water quality data from wells 52-87, 69-86, and 2-87 indicate inorganic contamination exists. Total dissolved solids (TDS) and major ion (calcium magnesium, sodium, chloride, sulfate, and bicarbonate) concentrations were higher than background during the

TABLE 2-10

VOLATILE ORGANIC COMPOUNDS DETECTED IN UNCONFINED GROUND WATER SECOND QUARTER 1989

Material	Well	Quarter	Carbon Tetra-chloride (µg/l)	Tetra-chloro-ethene (µg/l)	Tri-chloro-ethene (µg/l)	Methy-lene Chloride (µg/l)	1,1-Di-Chloro-ethene (µg/l)	1,1-Di-Chloro-ethane (µg/l)	1,2-Di-Chloro-ethane (µg/l)	1,1,1-Tri-chloro ethane (µg/l)	1,1,2-Tri-chloro ethane (µg/l)	1,1,2,2-Tetra chloro ethane (µg/l)	Toluene (µg/l)	Ethyl benzene (µg/l)	Acetone
Rocky Flats Alluvium	01-87	1 - Dry													
		2 - Dry													
	51-87	1 - Dry													
		2 - Dry													
	52-87	1		2J											
		2													
Colluvium	09-74	1		780E	7900		5300	180J	17J	10000	39J				
		2		2800J	6500J	5J	6600J	14J	17J	5700J	47J	5J	5J		
	10-74	1	660E	2J	410EU										
		2	2400J	17J	1200J	5J				8J			5J		
	63-86	1 - Dry													
		2 - Dry													
	69-86	1													
		2													
	02-87	1		35J	2J										
		2													
	04-87	1	11J	5J	99										
		2		6J	110J										
	06-87	1 - Dry													
		2													
	43-87	1		3400J	11000		6300	150J	16J	15000	29J				
		2		5900J	8500J		7900J	110J	14J	9000J	44J			5J	
	44-87	1 - Dry													
		2 - Dry													
	47-87	1 - Dry													
		2 - Dry													
	48-87	1 - Dry													
		2 - Dry													
	49-87	1 - Dry													
		2 - Dry													
	50-87	1 - Dry													
		2 - Dry													
	53-87	1 - Dry													
		2 - Dry													
	54-87	1 - Dry													
		2 - Dry													

TABLE 2-10
(continued)

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
SECOND QUARTER 1989

Material	Well	Quarter	Carbon Tetra-chloride (µg/l)	Tetra-chloro-ethene (µg/l)	Tri-chloro-ethene (µg/l)	Methy-lene Chloride (µg/l)	1,1-Di-Chloro-ethene (µg/l)	1,1-Di-Chloro-ethane (µg/l)	1,2-Di-Chloro-ethane (µg/l)	1,1,1-Tri-chloro ethane (µg/l)	1,1,2-Tri-chloro ethane (µg/l)	1,1,2,2-Tetra chloro ethane (µg/l)	Toluene (µg/l)	Ethyl benzene (µg/l)	Acetone
Colluvium (continued)	59-96	1													57B
		2													
Valley Fill Alluvium	58-86	1 - Dry													
		2 - Dry													
	64-86	1 - Dry													
		2		8J											
	68-86	1 - Dry													
		2 - Dry													
	55-87	1 - Dry													
		2 - Dry													
Weathered Sandstone	62-86	1													
		2													
	05-87	1													
		2													
	14-89	1 - Dry													
		2 - Dry													
	16-89	1 - Dry													
		2 - Dry													

J - Estimated value below Contract Required Detection Limit (CRDL) High concentrations associated with a "J" indicate a dilution of the sample was necessary for analysis, which increased the CRDL.

E - Estimated value beyond standard curve limits.

first quarter 1988. Wells 69-86 and 2-87 also had nitrate levels present above background. Wells 2-87 and 52-87 contained elevated manganese; wells 2-87 and 69-86 contained elevated zinc; and wells 52-87 and 69-86 contained elevated strontium. Selenium was also above background in well 69-86. Gross alpha, gross beta, uranium 233 + 234, uranium 235, and uranium 238 were above background in wells 1-87 and 52-87, and uranium 235 and 238 were above background in well 69-86. Total uranium concentrations in these wells were in the range of 8 to 15 picoCuries per liter (pCi/l). Although metals and other inorganics data do not exist for well 1-87, the elevated uranium in this "upgradient" well suggests the general inorganics contamination and low level organic contamination in this area may not be from these SWMUs. There are no wells directly downgradient of these SWMUs in the valley fill alluvium. Just upgradient of the 881 Hillside in the valley fill alluvium, wells 58-86 and 68-86 were dry.

Ground Water in Unweathered Bedrock

Two wells, 3-87 and 8-87, have been completed in unweathered bedrock downgradient of SWMUs 102, 103, 105, 106, 107, and 145. Review of the analytical data indicates that ground-water quality in these wells is generally within background range. Dissolved metals have been detected at levels slightly above background in wells 3-87 and 8-87 during first quarter 1988. These metals include barium (both wells), lithium (well 8-87), manganese (both wells), and nickel and strontium (well 8-87). The low concentrations of these metals above background, and the absence of volatile organic contamination suggest ground water in these deep bedrock units is not contaminated.

2.3.3.2 SWMUs 119.1, 119.2 and 130

Ground Water in Surficial Material and Weathered Bedrock

Thirteen monitor wells have been completed in the unconfined ground-water flow system downgradient of these SWMUs. These are: 9-74, 10-74, 63-86, 64-86, 4-87, 5-87, 6-87, 43-87, 44-87, 47-87, 48-87,49-87, 50-87, and 55-87. Several of these wells show significant ground-water contamination.

Five colluvial monitor wells have produced samples with elevated levels of volatile organic compounds: 9-74, 10-74, 43-87, 4-87, and 64-86. Wells 9-74, 10-74, 5-87, and 43-87 are located in SWMU 119.1. Well 4-87 is downgradient (south) of SWMU 119.1 and well 64-86 is southeast of well 4-87 in the valley fill. As shown in Table 2-10 and depicted in Figures 2-8 and 2-9, TCE, PCE and other organic contaminants have been detected in these wells. Carbon tetrachloride is a contaminant unique to well 10-74 indicating separate sources. Although 8 μg/l of PCE was present in second quarter sample from well 64-86, volatile organics were not present in samples taken during previous quarters. Therefore, the significance of this datum is not known at this time, and further monitoring is necessary to determine if organics have migrated to this location. Generally, it appears that volatile organic contamination in the colluvial ground water is limited in proximity downgradient of SWMU 119.1.

Comparison of first quarter 1988 inorganic analyses from the above wells with background indicate that wells 9-74, 10-74, 64-86, 4-87, 6-87 and 48-87 have levels of TDS and major ions significantly above background concentration. The remaining alluvial ground-water wells were dry during the first quarter 1988. These results are summarized below:

Inorganic Parameter	Maximum Concentration for Colluvium	Concentration (mg/l) 9-74	10-74	4-87	6-87	48-87	64-86
TDS	520	1253	1646	1756	1430	2081	*
Chloride	20.0	250	314	313	332	838	54.1 (40)**
Nitrate	0.18	8.67	36.7	2.60	*	0.32	*
Sulfate	86.0	230	311	500	285	218	168 (150)
Calcium	77.0	168	222	230	156	299	*
Magnesium	15.0	33	56	52	48	96	*
Sodium	99.0	170	178	265	219	211	106 (88)

* Not above background

** Well 64-86 is completed in valley fill alluvium. Parentheses indicate upper limit of background tolerance interval for valley fill alluvial ground water.

As shown in Figure 2-10, the source of the TDS appears to be upgradient of well 48-87, and a significant source of nitrate exists at or upgradient of well 10-74 (Figure 2-11). The presence of above-background sodium, sulfate, and chloride in well 64-86 which is approximately 700 feet southeast of SWMU 119.1, suggests that the inorganic plume is migrating into valley fill alluvium from the colluvial material downgradient of SWMU 119.1.

Dissolved metals have been detected above background in wells 9-74, 10-74, 69-86, 4-87, 6-87, 43-87, and 48-87 during the first quarter of 1988, and include aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, selenium, sodium, strontium, and zinc. Similar to carbon tetrachloride and nitrate, selenium is highest at well 10-74 [1.94 milligrams per liter (mg/l)], suggesting a source at or upgradient of this well (Figure 2-12). Selenium is at notably lower concentrations at 48-87 (0.03 mg/l) and 69-86 (0.08 mg/l) (Figure 2-12). At well 43-87, the selenium concentration is 0.5 mg/l, decreasing to 0.22 mg/l at 4-87, and is at background at well 64-86 in the valley fill. Selenium is also near background at well 6-87. Strontium is highest at well 48-87 (2.9 mg/l); it is lower (1.1 mg/l) upgradient at 69-86; it is approximately 2 mg/l in wells 43-87, 6-87, 4-87, and 10-74; and decreases to approximately 0.5 mg/l at well 64-86 in the valley fill alluvium (Figure 2-13). As shown in Figure 2-14, the highest nickel concentration also occurs in well 48-87 (1.18 mg/l) with lesser but significantly elevated concentrations occurring in wells 43-87 (0.60 mg/l), 4-87 (0.20 mg/l), and 6-87 (0.28 mg/l). Concentrations were at or near background at wells 69-86 and 64-86. High zinc concentrations occur in only wells 43-87 (2.13 mg/l) and 48-87 (2.45 mg/l) (Figure 2-15). It appears there may be separate sources for strontium, nickel, and zinc contamination near wells 48-87 and 43-87, because well 10-74 always has lesser concentrations of these metals. The remaining colluvial wells were either dry or contained insufficient water for metals sampling during each sampling period. None of the colluvial wells have been sampled for total metals analysis.

Uranium is the only radionuclide above background in alluvial ground water downgradient of SWMUs 119.1, 119.2 and 130 at wells 9-74, 4-87, 6-87, and 43-87 (Figure 2-16).

Total uranium concentrations above background in these wells during first quarter 1988 are as follows:

Well	Total Uranium Concentration (pCi/l)
9-74	27
4-87	35
6-87	53
43-87	44

Because concentrations of uranium are highest at well 6-87, it is conjectured that the source of uranium is upgradient of well 6-87 and more sidegradient to well 43-87 (Figure 2-16).

Uranium is also present above background in weathered sandstone well 5-87 (24 pCi/l) during first quarter 1988. Well 5-87 has a total uranium concentration that is close to the uranium concentrations for the alluvial ground water wells listed above and is in close proximity to those wells (Figure 2-16).

With respect to vertical contaminant migration, major ion and selenium concentrations indicate contamination of weathered bedrock ground water at monitoring well 5-87 and to a lesser extent at well 62-86. The significantly above background concentrations of sodium (84 mg/l), calcium (133 mg/l), chloride (267 mg/l), sulfate (485 mg/l), TDS (1170 mg/l), selenium (0.23 mg/l), and total uranium (24 pCi/l) in well 5-87 strongly suggest contamination of the ground water in this shallow sandstone. At well 62-86, the only analytes above background are sodium (50 mg/l), chloride (30 mg/l), TDS (275 mg/l), and selenium (0.06 mg/l). With the exception of selenium, these concentrations are within a factor of two of the background levels and are below drinking water standards (Section 2.4). It is therefore uncertain whether the sandstone ground water at well 62-86 is impacted.

Ground Water in Unweathered Sandstone

Monitoring well 45-87 is the only well completed in unweathered sandstone in the vicinity of SWMUs 119.1, 119.2 and 130. This well is located within SWMU 119.2. Ground-water quality in this well is generally within background range. No volatile organics were detected, and major ions and radionuclides were within background ranges in well 45-87. The following trace metals were detected at levels slightly above background during first quarter 1988: barium, copper, iron, lithium, manganese, potassium, and silver. The ground-water quality in unweathered sandstone in the vicinity of SWMU 119.2 indicates that this ground water apparently is not affected by SWMU 119.2. Although unconfined ground-water quality in the vicinity of SWMU 119.2 is poorly characterized due to the apparent lack of saturation in surficial materials.

2.3.3.3 Summary of Extent of Contamination

Organic, major ion, trace metal, and uranium contamination exist in ground water within surficial materials at the 881 Hillside Area. Generally, this contamination appears to have not migrated to any appreciable extent, although sodium, sulfate, and chloride contamination exists in valley fill ground water at well 64-86. [Concentrations of sulfate and chloride are below Applicable or Relevant and Appropriate Requirements (ARAR) at this location]. The chemical data suggest that the inorganic contamination (and low level organic contamination) at SWMUs 102, 103, 105, 107, and 145 may be due to SWMUs upgradient of the 881 Hillside Area. At SWMU 119.1 and 130, there appears to be at least four discrete sources of contamination:

1. a source of uranium upgradient of well 6-87;
2. a source of nitrate, selenium, and carbon tetrachloride at or upgradient of well 10-74;
3. a source of nickel, zinc, and several organics at or upgradient of well 43-87; and
4. a source of nickel and zinc at or upgradient of well 48-87.

TDS and strontium are ubiquitous contaminants of the ground water possibly released from all of the above sources, or from a central source upgradient of well 48-87.

Contaminants have migrated vertically. Contamination is notable in shallow bedrock ground water at well 5-87 and may be present in well 62-86. Deeper unweathered sandstone ground water does not appear impacted.

2.3.4 Surface Water

Surface water stations at the 881 Hillside Area are located along the South Interceptor Ditch, Woman Creek and at various seeps and ponds. Nine surface water stations in the vicinity of the 881 Hillside Area were sampled during field activities. The following discussion is based on volatile organic data from June 1989 (water was present at most stations and all data have been received and validated), and inorganic and radiochemistry data from first round 1989 surface water sampling (March 1 - May 1). The latter data are compared to first round 1989 background data to preliminarily assess if inorganic or radionuclide contamination exist at these stations. Surface water locations are shown on Figure 2-17 and data are presented in Appendix C.

2.3.4.1 South Interceptor Ditch

Surface water stations SW-45, SW-46, and SW-44 are located just south of Building 881. SW-45 monitors the foundation drain discharge from Building 881. This water flows into a skimming pond. Station SW-44 is the discharge from a pipe draining the skimming pond to the South Interceptor Ditch. The foundation drain is a vitrified clay pipe which is buried 14 to 20 feet deep along the western and southern sides of the 881 Building. The pipe drains water southward to a common pipe and then into the skimming pond. SW-46 is located at a pond formed by ground-water seepage from the 881 Hillside. SW-46 is west and hydraulically sidegradient of the skimming pond.

Surface water runoff from the 881 Hillside Area flows into the South Interceptor Ditch and then into Pond C-2. Surface water in Woman Creek is routed around Pond C-2; however, water in Pond C-2 is discharged to Woman Creek in accordance with the plant NPDES permit. SW-31 monitors water quality in the South Interceptor Ditch just downstream of SW-44. Surface water stations SW-66, SW-67, SW-68, SW-69 and SW-70 monitor the South Interceptor Ditch downgradient from the 881 Hillside.

Volatile organics have been detected in samples from SW-45 (Building 881 foundation drain discharge) and SW-46 (pond formed by ground-water seepage at 881 Hillside) but not from SW-44 (discharge to the Interceptor Ditch). PCE (8 μg/l) was the only detected volatile organic at SW-45 in May 1989 but was not detected in June 1989 at this station. Data from more recent sampling events are not yet available. Samples from SW-46 in May and June 1989 indicate that PCE was present at estimated concentrations below detection limits (3J μg/l and 2J μg/l, respectively). No other volatile organics were detected in samples from SW-46.

Volatile organics do not appear to be present at surface water stations SW-66, SW-67, SW-68, SW-69 and SW-70 (downgradient South Interceptor Ditch). Methylene chloride and acetone were present between 2 and 10 μg/l in all the stations; however, these compounds were also present in laboratory blanks. Toluene was present in a sample from SW-69 only in August 1989 at a level of 4J μg/l (also present below detection limits). No other volatile organics were detected in South Interceptor Ditch surface water stations downstream from the 881 Hillside Area.

Results of inorganic analyses of surface water samples from these stations indicates that TDS, nitrate and sulfate concentrations were above background. Concentrations were generally within a factor of two above background.

The following dissolved metals were present above background at these stations including: aluminum (2%), beryllium (1%), cadmium 1%), copper (1%), mercury (3%), strontium (29.6%), zinc (12.1%), chromium (1%), selenium (2%), and sodium (6.1%). Parentheses indicate the percent of the samples exceeding background range. The above metals were all present within a factor of two above upper tolerance intervals or ranges.

The only radionuclide detected above background was uranium. Dissolved concentrations of total uranium ranged from 2.5 to 8.5 pCi/l, whereas total concentrations ranged from 5.0 to 18.8 pCi/l.

2.3.4.2 Woman Creek

Surface water stations SW-32, SW-33, and SW-34 are located on Woman Creek directly south of the 881 Hillside and South Interceptor Ditch and upstream from the 903 Pad Area. Volatile organics were not detected in Woman Creek surface water, and results of inorganics analyses from these surface water stations were all within tolerance interval values calculated from Round 1 background surface water sampling results. Of the dissolved metals, only zinc (0.05 mg/l) was slightly elevated above background (0.03 mg/l) at SW-33. Dissolved and total radiochemistry data have not yet been received with the exception of fourth quarter 1987 results for SW-32.

2.3.5 Sediments

Bedload sediment samples were collected during 1989 site characterization from creeks and ditches that traverse the Rocky Flats Plant. Sediment stations have been established along the Woman Creek drainage downgradient of the 881 Hillside Area. Sediment stations SED-28, SED-29, and SED-25 are located within the South Interceptor Ditch in the Woman Creek drainage downgradient from surface water station SW-70. SED-30 and SED-31 are seeps on the South Interceptor Ditch berm near station SED-29. SED-27 and SED-26 are along Woman Creek just upstream of Pond C-2. These stations are also hydraulically downgradient of the 903 Pad Area and therefore impacts may also reflect this source.

Data discussed herein are for samples collected in March 1989. Volatile organic compound concentrations and concentrations of inorganic analytes and radionuclides that are above the background tolerance interval or range are presented in Appendix D.

With the exception of acetone which was present in the sediment sample from SED-30 at 200 mg/kg, there were no volatile organic compounds present above detection limits in the sediments of the Woman Creek drainage. The acetone also was present in the blank for this sample and was undetected in two other sampling events for this station in 1989. Acetone is not a likely sediment contaminant at this location.

Of the metals, beryllium, silver, and tin were notably elevated above background in the sediment of the South Interceptor Ditch and Woman Creek. Concentrations of silver are greater than five times the upper limit of the background range [as high as 49.1 milligrams per kilogram (mg/kg)] at stations SED-29, SED-30, and SED-25. Beryllium was not detected in the background samples (<1.1 mg/kg) but occurs at concentrations ranging from 3.8 to 15.0 mg/kg in all the sediment samples collected from the South Interceptor Ditch and Woman Creek. Although tin was not above background (<22.8 mg/kg) at SED-27, SED-28, and SED-31, it occurred in a range from 364 to 819 mg/kg in stations SED-25, SED-26, SED-29, and SED-30.

Of the radionuclide data that exist for the March 1989 sampling, it is noted that plutonium was above background at stations SED-25, SED-26, SED-29, and SED-30, ranging in concentration from 0.3 to 3.3 pCi/g. This is likely attributable to wind dissemination of plutonium contaminated surface soil from the 881 Hillside Area.

2.3.6 Air

Air quality studies at the Plant are performed continuously and reported annually in the Annual Environmental Monitoring Reports (e.g., Rockwell International, 1975 through 1985, 1986b, and 1987b). In addition, the air pathway was further characterized in Rockwell International (1986f).

Air samplers for routine ambient air monitoring at the Plant are located at various locations on and off the Plant site. The ambient air program monitors radionuclide concentrations; conventional air quality parameters are also monitored on site at a dedicated location inside the perimeter security fence, west of the East Guard Gate.

The Plant Radioactive Ambient Air Monitoring Program (RAAMP) consists of 51 high-volume particulate air samplers which operate continuously. Twenty-three of the 51 samplers are within or directly adjacent to the Plant security area (on-site samplers) and 14 are located around the property boundary (perimeter samplers). An additional 14 samplers are located in neighboring towns (community samplers).

The 903 Pad Area is recognized as the principal source of airborne plutonium contamination at the Plant. Historically, the particulate samplers located immediately east, southeast, and northeast of the 903 Pad, Mound, and East Trenches Areas have shown the highest plutonium concentrations. This finding is corroborated by the results of soil surveys which indicate elevated plutonium concentrations to the east, particularly the southeast of the area. However, the RAAMP has found ambient air samples to be well within applicable regulations and guidelines for the protection of human health and the environment for all radioactive contaminants (Rockwell International, 1987a).

2.3.7 Biota

The biota at the 881 Hillside Area have not specifically been previously studied, however studies on the biota at the 903 Pad, Mound and East Trenches Area have been conducted. A survey was conducted for the Final Environmental Impact Statement, Rocky Flats Plant Site (U. S. DOE, 1980), and previous studies were summarized in the Radioecology and Airborne Pathway Data Summary Report (Rockwell International, 1986f). The Radioecology and Airborne Pathway Data Summary Report addresses the plutonium released from the 903 Drum Storage Site and its effects on the immediate environment. Field studies were conducted over several years which compared various biological measurements and pathological data between ecologically similar study areas of widely varying plutonium levels. Soil plutonium concentrations were measured along with biological measurements such as vegetation community structure and biomass, litter mass, arthropod community structure and biomass, small mammal species occurrence, population density, biomass, reproduction, and physical size of whole carcasses and organs. In addition, pathological examination of small mammals, including x-ray for skeletal sarcomas, microscopy for lung tumors, and necropsy for general pathology and parasite occurrence were carried out.

Aquatic studies, conducted by Colorado State University, examined phytoplankton, some detritus and small zooplankton uptake of plutonium from the B-series holding ponds. This study showed than an "increase in trophic-level concentration of plutonium did not occur apparently due to a selective mechanism that discriminated against plutonium at this level. This would result in a decreased potential hazard when considering the transfer of plutonium through ingestion routes" (Paine, 1980).

Other aquatic studies revealed that 77% of the plutonium associated with crayfish is found in their exoskeleton. Fish flesh and bone from the A and C-series ponds were never above the minimum detectable activity for plutonium.

2.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that Fund-financed, enforcement, and Federal facility remedial actions comply with applicable or relevant and appropriate (ARAR) Federal laws, or more stringent promulgated State laws.

Health-based, chemical-specific ARARs pertinent to ground-water quality have been identified for the EPA TCL organic and Target Analyte List (TAL) inorganic compounds found above detectable levels. Radionuclides and conventional pollutants have also been identified and screened. Chemical-specific ARARs are derived primarily from federal and state health and environmental statutes and regulations. Health effect assessments, health advisories, chemical advisories, and guidance documents were also considered when establishing clean-up standards, but were not considered to be ARARs. These and any proposed standards are classified as items to be considered (TBCs). A summary of chemical-specific ARARs for the contaminants found at the 881 Hillside Area is presented in Table 2-11. When more than one chemical-specific ARAR was identified for a contaminant, a screening process was used to determine the specific ARAR to be applied. This screening process involves three steps as outlined below:

1. The most stringent human health or agricultural-based promulgated standard among the Safe Drinking Water Act (SDWA), Maximum Contaminant Level (MCL), and CDH ground and surface water standards was first applied (applicable).

2. For a RCRA Appendix VIII hazardous constituent, in the absence of any promulgated standard in step 1 above, the most stringent RCRA Land Disposal Restriction or RCRA Subpart F limit was applied (relevant and appropriate).

3. In the absence of an ARAR in steps 1 or 2 above, the most stringent of the Clean Water Act Water Quality Criteria, or the proposed CDH ground-water and surface water standards was applied (TBC).

The screening process includes consideration of both ground-water and surface water standards because of the significant interaction of alluvial ground water and surface water in the drainages of the Rocky Flats Plant. Of the elements/compounds detected in alluvial ground water at the 881 Hillside Area, there are no ARARs for calcium, magnesium, potassium, sodium, bicarbonate, cesium, and strontium. However, the TDS ARAR establishes the acceptable aggregate concentration for the above major ions (excludes cesium and strontium). Until an acceptable risk based concentration is established for cesium and strontium, their background concentration is TBC.

As can be seen in Table 2-11, several of the volatile organics, metals, and major ions that were analyzed have exceeded chemical-specific ARARs during the period 1987 to 1989 at some locations in the 881 Hillside Area. This is not to say that releases of these constituents are occurring, for the concentrations of some substances may be due to a past release or to natural geochemical processes. However, the listing of Table 2-11 has been presented to

TABLE 2-11
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a]	ARAR (ug/l)	Detection Limit (ug/l)	Standard Criteria or Guidance	Comment
Organic Compounds					
Acetone	19	50	10	RCRA LDR is relevant and appropriate (R&A)	ARAR is not exceeded
Carbon Tetrachloride	2400J	5	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
1,1 Dichloroethane	180J	5U	5	RCRA Subpart F, Appendix IX Substance is TBC	TBC is exceeded
1,2 Dichloroethane	17J	5	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
1,1 Dichloroethene	7900J	7	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
Methylene Chloride	17B	5U	5	RCRA Subpart F is R&A	ARAR is exceeded
Tetrachloroethene	5900J	10	5*	CDH Surface Water; Fish and Water Ingestion Standard is applicable	ARAR is exceeded
Toluene	5J	2420	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
1,1,1 Trichloroethane	15,000	200	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
1,1,2 Trichloroethane	47J	10	5*	CDH Surface Water; Fish and Water Ingestion Standard is applicable	ARAR is exceeded
Trichloroethene	11,000	5	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
Carbon Disulfide	3J	5U	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded

TABLE 2-11 (cont'd)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a]	ARAR (ug/l)	Detection Limit (mg/l)	Standard Criteria or Guidance	Comment
Metals					
Aluminum	0.26	5.0	0.20	CDH Agriculture Standard is applicable	ARAR is not exceeded
Antimony	0.0798	0.06U	0.06	RCRA Subpart F is R&A	ARAR is exceeded
Arsenic	0.010	0.05	0.01	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Barium	0.3110	1.0	0.20	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Beryllium	0.003J	0.1	0.005	CDH Agricultural Standard is applicable	ARAR is not exceeded
Cadmium	0.0017	0.01	0.005	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Calcium	355.99	NS	5	No Standard	--
Cesium	0.04J	NS	1	No Standard	Background is TBC
Chromium III	0.0782	.05	0.01	CDH Surface Water; Drinking Water Standard is applicable	Analytical result is total chromium. ARAR may be exceeded
Chromium VI	0.0782	.05	0.01	CDH Surface Water; Drinking Water Standard is applicable	Analytical result is total chromium. ARAR may be exceeded
Copper	0.9515	0.2	0.025	CDH Agriculture Standard is applicable	ARAR is exceeded

TABLE 2-11 (cont'd)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a]	ARAR (ug/l)	Detection Limit (mg/l)	Standard Criteria or Guidance	Comment
Metals (cont.)					
Iron	0.4065	0.3	0.1	CDH Surface Water; Drinking Water Standard is applicable	Analytical results are soluble iron; soluble iron exceeds ARAR
Lead	0.024	0.05	0.005	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded not exceeded
Lithium	0.7	2.5	0.1	CDH Ground Water Standard is applicable	ARAR is not exceeded
Magnesium	95.507	NS	5	No Standard	--
Manganese	0.9586	0.05	0.015	CDH Surface Water; Drinking Water Standard is applicable	Analytical results are soluble manganese; ARAR is exceeded
Mercury	0.9	0.002	0.0002	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
Molybdenum	0.0533	0.1	0.2*	CDH Agriculture Standard is	ARAR is not exceeded applicable
Nickel	1.1827	0.2	0.04	CDH Agriculture Standard is applicable	ARAR is exceeded
Potassium	12.3	NS	5	No Standard	--
Selenium	3.2	0.01	0.005	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded

TABLE 2-11 (cont'd)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a]	ARAR (ug/l)	Detection Limit (mg/l)	Standard Criteria or Guidance	Comment
<u>Metals (cont.)</u>					
Silver	0.0094	0.05	0.01	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Sodium	341.74	NS	5	No Standard	--
Strontium	2.9066	NS	0.2	No Standard	Background is TBC
Thallium	0.01	0.01U	0.01	RCRA Subpart F is R&A	ARAR is exceeded
Vanadium	0.0368	0.1	0.05	CDH Agriculture Standard is applicable	ARAR is not exceeded
Zinc	2.4559	2.0	0.02	CDH Agriculture Standard is applicable	ARAR is exceeded

TABLE 2-11 (cont'd)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a]	ARAR (ug/l)	Detection Limit (mg/l)	Standard Criteria or Guidance	Comment
Conventional Pollutants					
pH	5.6-8.5	6.5-9.0	0.1	CDH Ground Water Standard is applicable	ARAR is exceeded
Nitrite	-	1.0	5*	CDH Ground Water Standard is applicable	Analytical results are total nitrate plus nitrate nitrogen. Reanalysis required to determine if nitrite ARAR is
exceeded.					
Nitrate	55	10.0	5	CDH Ground Water Standard is applicable	Analytical results are total nitrate nitrogen. Results indicate that nitrate ARAR is exceeded.
Chloride	838	250	5	CDH Ground Water Standard is applicable	ARAR is exceeded
Sulfate	700	250	5	CDH Ground Water Standard is applicable	ARAR is exceeded
Bicarbonate as $CaCO_3$	502	NS	10	No Standard	
T.D.S.	2374	400	5	CDH Ground Water Standard is applicable	ARAR is exceeded

TABLE 2-11 (cont'd)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 881 HILLSIDE AREA

Chemical	Maximum In 881 Hillside Area Alluvial Ground Water[a]	ARAR (ug/l)	Detection Limit (pCi/l)	Standard Criteria or Guidance	Comment
Radionuclides					
Gross Alpha	319	7	2	CDH Surface Water Standard is applicable	ARAR is exceeded
Gross Beta	286	5	4	CDH Surface Water Standard applicable	ARAR is exceeded
$Pu^{238,239,240}$	<0.01[c]	0.05	0.01	CDH Surface Water Standard is applicable	ARAR is not exceeded
Am^{241}	<0.01[c]	0.05	0.01	CDH Surface Water Standard is applicable	ARAR is not exceeded
H^3	777	500	400	CDH Surface Water Standard is applicable	ARAR is exceeded
$Sr^{89,90}$	5.6	8	1	CDH Surface Water Standard is applicable	ARAR is not exceeded
$Uranium^{total}$	58.9	5	1.8	CDH Surface Water Standard is applicable	ARAR is exceeded

(a) - Maximum compound concentrations determined from first and second quarter 1989 data.
(b) - Maximum compound concentrations determined from 1987 and 1988 database.
U - Detection limit
J - Estimated below detection limit
B - Compound also present in blank
TBC - To be considered
(c) - Below minimum detectable activity (MDA)
* - Detection limit exceeds ARARs

identify parameters for which analyses should be made in Phase III and their respective minimum acceptable detection limits. The draft final FS will evaluate technologies that address these constituents.

2.5 SAMPLING AND ANALYSIS REQUIREMENTS FOR REMEDIAL ALTERNATIVES EVALUATION

The purpose of this section is to identify potential remedial technologies which are consistent with the available information regarding contamination at the 881 Hillside Area. Based on the available site information, the contaminated media or areas for which remedial alternatives will be developed include wastes, soil/sediment, ground water, and surface water. The following general remedial response actions were identified for further review and evaluation in the draft FS (Rockwell International, 1988b).

- Complete or partial removal of wastes and contaminated soils;
- In-situ contaminated soils treatment;
- Ground-water collection;
- Infiltration and ground-water containment controls;
- In-situ ground-water treatment/immobilization; and
- Ground-water/surface water treatment.

Combinations of these general response actions are appropriate and were evaluated during the draft FS. Table 2-12 presents these general response actions along with applicable component technologies.

At the time the draft FS was prepared, the extent and nature of contamination at the 881 Hillside Area was not completely understood. For example, organic contamination of soils may have been underestimated because maximum concentrations occurred in samples not necessarily collected from "hot spots", and the volatile organic data have since been rejected in the validation process. The draft FS did not evaluate treatment and/or disposal of organic contaminated soil; however, the Phase III RI may indicate such an evaluation is in order. With respect to inorganic contaminants, the draft FS did not evaluate treatment technologies for

TABLE 2-12

RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GENERAL RESPONSE ACTIONS	ASSOCIATED REMEDIAL TECHNOLOGIES
Complete or Partial Removal of Contaminated Soils	• Off-Site Landfill • On-Site Treatment*/Backfill
In-Situ Contaminated Soils Treatment	• Immobilization • Soil Flushing • Vapor Extraction
Ground-Water Collection	• Well Array • Subsurface Drains
Infiltration and Ground-Water Containment Controls	• Capping • Subsurface Barriers
In-Situ Ground-Water Treatment/ Immobilization	• Immobilization • Aeration • Bioreclamation
Ground-Water/Surface Water Treatment	• Biological Treatment • UV/Peroxide or UV/Ozone • Air Stripping • Carbon Adsorption • Ion Exchange • Electrodialysis • Reverse Osmosis

* Thermal Treatment, Solvent Extraction, Attrition Scrubbing for Plutonium Decontamination

their removal. Although this was performed for the 881 Hillside interim action (U.S. DOE, 1990a), the performance of the interim action treatment system will be important input in reevaluating these technologies for the draft final FS. Lastly, the extent of inorganic contaminated ground water is beyond the collection system proposed for the interim action. Remedial alternatives that address this issue will be evaluated in the draft FS. As shown in Table 2-12, there are specific requirements that are necessary to evaluate the technologies identified in Table 2-13. These data will provide for a thorough comparative evaluation of all appropriate technologies with respect to implementability, effectiveness, and cost, and allow for informed decisions to be made with respect to selection of preferred technologies. The Field Sampling Plan (Section 5.0) reflects these information requirements.

TABLE 2-13

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED
Off-Site Disposal	Evaluate whether material are acceptable for off-site disposal	- 40 CFR 268 Table CCWE and Appendix III Analyses - Full Suite of Radionuclide Analyses
	Cost Analysis	- Vertical and Horizontal Extent* of Contamination
Thermal Treatment	Effectiveness	- Full Suite of Organic and Inorganic Analyses*
	Cost Effectiveness	- BTU Content
Solvent Extraction	Effectiveness (adsorption characteristics of soils)	- Soil Type - Soil Organic Matter Content
Immobilization (soils)	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
Soil Flushing/Bioreclamation	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD
Vapor Extraction	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
Well Array/Subsurface Drain	Hydraulic conductivity Storativity (transient flow)	- Aquifer tests - Hydrogeologic characteristics
Capping/Subsurface Barriers	Suitability of On-Site Soils for Use	- Gradation (Sieve Analysis) - Atterberg Limits (Plasticity Tests)
	Effectiveness	- Location of Subcropping Sandstones - Hydraulic Conductivity of Bedrock Materials
	Construction Feasibility	- Grade - Depth to Bedrock - % Moisture - Compaction (Proctor) - Permeability (Triaxial Permeability) - Strength (Triaxial or Direct Shear)

TABLE 2-13 (cont.)

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED
Immobilization (Ground Water Contaminants)	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
In-Situ Aeration (Ground Water)	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
In-Situ Bioreclamation (Ground Water)	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD - Dissolved Oxygen - NO_3, PO_4^{3-}, pH - Microbial Populations
Above Ground Biological Treatment	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD
UV Peroxide Oxidation	Process Control	- Iron and Manganese
Air Stripping	Process Control	- Hardness

* The nature and extent of contamination determined through soils and water analyses for the parameters listed in Tables 2-5 and 2-9 is critical to determining the technical feasibility and cost effectiveness of the technologies listed here.

3.0 PHASE III RI/FS WORK PLAN DATA QUALITY OBJECTIVES

The primary objective of a RI is to collect the data necessary to determine the nature, distribution, and migration pathways of contaminants. The RI also supports the evaluation of remedial alternatives (U.S. EPA, 1987). The five general goals of a RI are:

1) characterize site physical features;
2) define contaminant sources;
3) determine the nature and extent of contamination;
4) describe contaminant fate and transport; and
5) provide a baseline risk assessment (U.S. EPA, 1988a).

Data quality objectives (DQOs) are qualitative and quantitative statements which specify the quality and quantity of data collection required by the RI (U.S. EPA, 1987). Through application of the DQO process, site-specific RI/FS goals are established, and data needs are identified for achieving those goals. This section of the RI/FS Work Plan reviews conclusions from the Phase I and II RI as a basis for Phase III RI objectives and identifies data needs to meet the outlined objectives.

3.1 PHASE I AND II RI CONCLUSIONS

Several investigations have been conducted in the vicinity of the 881 Hillside Area to date as discussed in Sections 1.0 and 2.0. General conclusions from these investigations are as follows.

1) Surficial materials in the area consist of Rocky Flats Alluvium, colluvium and valley fill alluvium.
2) Bedrock beneath surficial materials consists of Arapahoe Formation claystones and sandstones dipping slightly to the east (less than two degrees). Bedrock materials are weathered below the base of surficial materials.
3) Unconfined ground-water flow occurs in surficial materials, subcropping sandstones, and potentially in weathered subcropping claystones. The flow system in surficial materials is not fully saturated year round. Flow in weathered claystones has not been sufficiently documented, and flow directions in subcropping sandstones are poorly defined due to the complex stratigraphy.

4) Confined ground-water flow occurs in deeper sandstones. This flow system is poorly defined at this time due to the complex stratigraphy and facies changes.

5) Ground-water recharge occurs as infiltration of incident precipitation and flow from ditches and surface water drainages.

6) Discharge from the unconfined ground-water flow system occurs as evapotranspiration, seeps and springs at the edge of the Rocky Flats pediment, to surface water in Woman Creek and South Interceptor Ditch, and to bedrock sandstones and claystones.

7) Wastes have been buried at SWMU 102 (oil sludge pit site), and SWMU 103 (chemical burial site). In addition, wastes were potentially dumped or discharged at the liquid dumping site (SWMU 105) and outfall site (SWMU 106). Organic contaminants have been released from the Hillside Oil Leak Site (SWMU 107), and the multiple solvent spill site SWMU 119.1. Soil contaminated with low levels of plutonium has been disposed of at SWMU 130; however, the Phase I and II RI did not detect radionuclide contamination. Releases from SWMU 106 (outfall site) and SWMU 105 (out-of-service fuel oil tanks) have not been determined based on the Phase I and II RI.

8) Boreholes were drilled within and adjacent to SWMUs in the Phase I and II RIs, and soil samples were collected and analyzed for HSL organics and metals, radionuclides, and inorganics. Volatile chlorinated hydrocarbon contamination is apparently limited to soils in the vicinity of BH01-87, BH57-87, and BH58-87. However, further characterization of soils beneath SWMUs is needed.

9) Surficial soils in the area are contaminated with plutonium and americium possibly due to wind dispersal of these radionuclides. Based on soil sampling results, these compounds appear to be limited to the surface; although further definition of source area(s) and extent of contamination is needed.

10) Results of RI surface water and ground-water sampling at the 881 Hillside Area indicate that major ions, trace metals, and radionuclides are present above background. Volatile organics are also present in ground water downgradient of the 881 Hillside. Therefore, further characterization of contaminant sources and pathways is warranted.

11) Ground water in surficial materials contains volatile organic compounds. The principal volatile organics present are PCE and TCE. The extent of these contaminants in alluvial ground water has not been fully determined.

12) Trace metals including strontium, selenium, nickel, and zinc in addition to uranium, are elevated in the unconfined ground-water flow system. The source and extent of these contaminants has not been defined.

13) Elevated uranium has been detected in the South Interceptor Ditch. The source of the uranium has not been determined.

3.2 SITE-SPECIFIC PHASE III RI OBJECTIVES AND DATA NEEDS

Based on the Phase I and II RI conclusions and the conceptual site model presented in Section 2.0, the site-specific Phase III RI objectives and associated data needs have been developed (Table 3-1). Specific plans for obtaining the needed data are presented in Section 5.0 (Field Sampling Plan).

The highest quality data possible will be collected by following the Rocky Flats Plant ER Program Standard Operating Procedures (SOP) and through adherence to the Rocky Flats Plant ER Program Quality Assurance/Quality Control (QA/QC) Plan. Organic and metal analyses will be performed using CLP routine analytical services (RAS), and other analyses (radionuclides and inorganics) will be performed in accordance with the QA/QC plan specified methods. In addition, analytical methods with detection limits below or near chemical-specific ARARs (see Table 2-11) will be used to facilitate comparison of resulting data to ARARs.

TABLE 3-1
PHASE III RI/OBJECTIVES AND DATA NEEDS

Objective	Data Need
Characterize Site Physical Features	
1) Determine the extent of saturation and ground-water flow directions for the unconfined flow system both spatially and temporally.	- Install additional monitoring wells and piezometers. - Maintain a database of water levels from which potentiometric surface maps, saturated thickness maps, cross sections, and hydrographs can be prepared.
2) Describe the interaction between the surface water and ground-water pathways.	- Compare water levels and water quality data from surface water sampling locations and ground-water monitoring wells to evaluate the interconnection between these two media. Data analysis will also rely on ground-water flow directions and seep locations.
3) Quantify material properties	- Perform aquifer tests to develop hydraulic conductivity and storativity values for surficial materials.
Characterize Contaminant Sources	
1) Characterize the nature and distribution of waste materials remaining on-site.	- Collect samples from boreholes drilled directly through SWMUs where possible. Collect waste samples as well as soil samples from beneath the wastes. Analyze samples for TCL volatiles, semi-volatiles, and pesticides/PCBs, TAL metals, as well as radionuclides and inorganics.
2) Characterize soils beneath wastes as well as soils at sites where wastes have been removed as potential contaminant sources.	- Same as above.
3) Identify which sites or subareas of sites are sources of contaminants in ground water.	- Install alluvial ground-water monitoring wells directly beneath sites to assess ground-water levels and quality. - Install alluvial ground-water monitoring wells directly up- and downgradient of each site to pinpoint the source of contaminants.

TABLE 3-1 (continued)
PHASE III RI/OBJECTIVES AND DATA NEEDS

Objective	Data Need
Characterize the Nature and Extent of Contamination	
1) Determine the horizontal and vertical extent of surficial radionuclide soil contamination due to wind dispersion.	- Collect surficial soil scrapes in the study area following Colorado Department of Health sampling procedures and analyze for radionuclides.
2) Determine the nature and extent of ground-water contamination in surficial materials.	- Install alluvial ground-water monitoring wells in surficial materials located between areas of known ground-water contamination and areas with no ground-water contamination to delineate the extent. Collect ground-water samples and analyze for TCL volatiles, semi-volatiles and pesticides/PCBs, TAL metals, radionuclides, and inorganics
3) Characterize surface water quality.	- Continue collection of surface water from existing monitoring stations on a quarterly basis. Analyze samples for TCL volatiles, TAL metals, radionuclides, and inorganics. Analyze surface water samples for both dissolved and total metals and radionuclides to determine if constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations.
Provide A Baseline Risk Assessment	
1) Describe contaminant fate and transport.	- Use existing literature and field data to describe the physicochemical processes associated with site contaminants.

Objective	Data Need
Provide A Baseline Risk Assessment	
2) Assess the threat to public health and the environment from the no action remedial alternative.	- Prepare a baseline risk assessment as part of the RI data analysis based on Phase I and Phase II RI results.

4.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

4.1 REMEDIAL INVESTIGATION TASKS

4.1.1 Task 1 - Project Planning

The project planning task includes all efforts required to initiate this Phase III RI of Operable Unit No. 1. Activities undertaken for this project have included detailed review of the Phase I and II RI results; responses to EPA comments on the FS and Phase II RI (Rockwell International, 1989a); responses to DOE comments on the FS; historical aerial photography; and preliminary evaluation of ARARs. Results of these activities are presented in Sections 1.0 (Introduction) and 2.0 (Phase I and Phase II Site Evaluation).

Two project planning documents, including this Work Plan, have been prepared which pertain to this Phase III RI as required by the draft IAG between DOE, EPA, and CDH. This Work Plan presents results of the project planning task in addition to plans for the Phase III RI. A Field Sampling Plan (Section 5.0) presents the locations, media, and frequency of sampling efforts. The second document required by the IAG is a Sampling and Analysis Plan (SAP). Included in the SAP are a Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOP) for all field activities. The current versions (January 1989) of the Rocky Flats Plant ER Program QA/QC Plan (Rockwell International, 1989d) and SOP have been submitted previously to EPA and CDH. The QA/QC Plan and SOP are being revised and will be submitted in July 1990 in accordance with the draft IAG.

4.1.2 Task 2 - Community Relations

In accordance with the draft IAG, the Communications Department at Rocky Flats is developing a Plant-wide Community Relations Plan to actively involve the public in the decision-making process as it relates to environmental restoration activities. A work plan has been completed and forwarded to EPA, CDH, and the public for review. The work plan specifies activities planned to complete the ER Program Community Relations Plan, including plans for community interviews. The draft Community Survey Plan was completed in January 1990, and the draft Community Relations Plan will be completed in September 1990 in accordance with the draft IAG schedules. Accordingly, a site-specific Community Relations Plan is not required for Operable Unit No. 1. ER Program community relations activities include participation by Plant representatives in: informational workshops; meetings of the Rocky Flats Environmental Monitoring Council; briefings for the public on proposed remedial action plans; and sponsoring meetings to solicit public comment on various ER program plans and actions.

The Communications Department also is continuing other public information efforts to keep the public informed of environmental restoration activities and other issues which relate to Plant operations. A Speakers Bureau program sends speakers to civic groups and educational organizations, while a public tour program allows the public to visit Rocky Flats. An Outreach Program is also in place where Plant officials will visit elected officials, the news media, and business and civic organizations to further discuss issues related to Rocky Flats and environmental restoration activities. The Communications Department also receives numerous public inquiries which are answered during telephone conversations, or by sending written informational materials to the requestor.

4.1.3 Task 3 - Field Investigation

The Phase III RI field investigation is designed to meet the objectives outlined in Section 4.0. The following activities will be performed as part of the field investigation:

- Drill and sample soils and wastes within SWMUs;
- Install and sample ground-water monitoring wells;
- Perform aquifer tests and geotechnical tests; and
- Collect surface water and sediment samples.

Sample locations, frequency, and analyses are presented in Section 5.0. All field activities will be performed in accordance with the Rocky Flats Plant ER Program SOP.

4.1.4 Task 4 - Sample Analysis and Data Validation

Analytical methods for chemical analyses are provided in the ER Program QA/QC Plan (Rockwell International, 1989d). Also provided in this document are the analytical detection limits, sample container and volume requirements, preservation requirements, and sample holding times.

Data will be reviewed and validated by the ER Program staff. Results of data review and validation activities will be documented in data validation reports. EPA data validation functional guidelines will be used for validating organic and inorganic (metals) data (U.S. EPA, 1988b). Validation methods for radiochemistry and major ions data have not been published by the EPA; however, data and documentation requirements have been developed by ER Program QA staff. Data validation methods for these data are derived from these requirements. Details of the data validation process are described in the QA/QC Plan (Rockwell International, 1989d).

4.1.5 Task 5 - Data Evaluation

Data collected during the Phase III RI will be incorporated into the existing database and used to better define site characteristics, source characteristics, the nature and extent of contamination. These data will then be used during the FS to support the evaluation of proposed remedial alternatives.

4.1.5.1 Site Characterization

Geologic and hydrologic data will be incorporated into existing site maps and cross-sections. Geologic data will be used to detail the stratigraphy of surficial materials and weathered bedrock within source areas and to map the eastern extent of paleochannels in the top of bedrock. Hydrologic data will be used to evaluate seasonal variations in water levels, ground-water flow and the extent of saturated surficial materials. Also evaluated will be storativity, ground-water velocity, and the interaction between ground water and surface water.

4.1.5.2 Source Characterization

Analytical data from source boreholes will be used to:

- Verify SWMU locations;
- Characterize the nature of source contaminants;
- Characterize the lateral and vertical extent of source contaminants;
- Determine the maximum on-site contaminant concentrations; and
- Quantify the volume of source materials.

4.1.5.3 Nature and Extent of Contamination

Analytical data from soil, sediment, ground-water, and surface water sampling efforts will be used to characterize the nature and extent of contamination. The criteria for the identification of contamination will be analyte specific. For organic compounds, any detectable concentrations in samples that are not attributable to laboratory contamination will be considered likely evidence of contamination. For inorganic compounds (including radionuclides) only those concentrations which exceed expected concentrations in background shall constitute evidence of contamination. The statistical techniques which shall be used to compare concentrations of inorganic compounds collected as part of the Phase III RI to background concentrations are documented in the Background Geochemical Characterization Report (Rockwell International, 1989c). Essential to the implementation of these statistical techniques for ground-water and borehole samples is the classification of each analytical datum by an appropriate geologic unit (such as Rocky Flats Alluvium or colluvium). This identification of the appropriate geologic unit will be based on geological data collected during the Phase III RI.

The extent of contamination will be delineated through the use of contaminant isopleths maps and possibly cross sections. The possibility of using kriging to contour the isopleths of the most widely distributed contaminants will be investigated, and kriged contours will be generated if appropriate. Investigations to date indicate difficulty in identifying the source of contamination because of the close proximity of several possible sources. The statistical technique of principal component analysis will be investigated as a method of identifying the releases from different sources. The ability to estimate the individual effects of multiple sources at intermediate sampling sites will aid in the mapping of plumes and in the understanding of contaminant transport by the ground-water flow system.

Comparisons of analytical data from ground water and surface water will be made to investigate the movement of contaminants from one pathway to another. Temporal variations of contaminant concentrations in ground water and surface water will be evaluated both for seasonality and long-term trends.

Analytical data from surficial soil scrapes and vertical soil profiles will be evaluated in order to characterize the areal and vertical distribution of plutonium and americium contamination at the 881 Hillside Area.

4.1.6 Task 6 - Baseline Risk Assessment

A baseline risk assessment will be prepared for the 881 Hillside Area as part of the Phase III RI to evaluate the potential threat to the public health and the environment in the absence of remedial action. A risk assessment was previously prepared as part of the draft FS (Rockwell International, 1988b). The baseline risk assessment will evaluate data collected during Phase III and use information, as appropriate, developed in the original risk assessment. The baseline risk assessment will provide the basis for determining whether or not remedial action is necessary in the area and serve as the justification for performing remedial action (U.S. EPA, 1988a).

Several objectives will be accomplished under the risk assessment task including identification and characterization of the following (U.S. EPA, 1988a):

- toxicity and levels of hazardous substances present in relevant media (e.g., air, ground water, soil, surface water, sediment, and biota);
- environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes and hydrogeological conditions;
- potential human and environmental receptors;
- potential exposure routes and extent of actual or expected exposure;
- extent of expected impact or threat; and the likelihood of such impact or threat occurring (i.e., risk characterization); and
- level(s) of uncertainty associated with the above.

The public health risk assessment and the environmental evaluation will be performed in accordance with EPA and other guidance documents listed in Table 4-1. The risk assessment will address the potential public health and environmental impacts associated with the site under the no-action alternative (no remedial action taken). This assessment will aid in the selection of site remedies based on the contaminants of concern and the environmental media associated with potential risks to public health and the environment.

4.1.6.1 Public Health Evaluation

The risk assessment process is divided into four tasks (U.S. EPA, 1988a), including:

- Contaminant identification;
- Exposure assessment;
- Toxicity assessment; and
- Risk characterization.

The task objectives and description of work for each task are described below.

TABLE 4-1

EPA GUIDANCE DOCUMENTS WHICH WILL BE USED IN THE RISK ASSESSMENT TASK

- Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A, Interim Final (U.S. EPA, 1989a)

- Superfund Exposure Assessment Manual (U.S. EPA, 1988c)

- Exposure Factors Handbook (U.S. EPA, 1989b)

- The Endangerment Assessment Handbook (U.S. EPA, 1985)

- CERCLA Compliance With Other Laws Manual (U.S. EPA, 1988d)

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U.S. EPA, 1988a)

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (U.S. EPA, 1989c)

- Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual (U.S. EPA, 1989d)

- Data Quality Objectives for Remedial Response Activities: Development Process (U.S. EPA, 1987)

Contaminant Identification

The objective of contaminant identification is to screen the information that is available on hazardous substances or wastes present at the site and to identify contaminants of concern to focus subsequent efforts in the risk assessment process. Previous work characterizing aspects of the Rocky Flats Plant and the surrounding area has been done. Additional sampling and analysis of various media will take place in order to support the human health risk assessment, the ecological assessment and to characterize the site. For this risk assessment, all contaminants at Operable Unit No. 1 will be considered unless the following criteria are met for their deletion:

- Determination that a chemical has not been detected;
- Environmental fate information which shows that exposure will not occur; or
- A low frequency of occurrence (less than 10 percent) in environmental media.

All chemicals that are deleted and the rationale for their deletion will be discussed in the completed risk assessment.

Exposure Assessment

The objectives of the exposure assessment are to identify actual or potential exposure pathways, to characterize potentially exposed populations, and to determine the extent of exposure. An exposure pathway is comprised of four elements:

1) a source and mechanism of chemical release to the environment;
2) an environmental transport medium (e.g., air, groundwater) for the released constituent;
3) a point of potential contact of humans or biota with the affected medium (the exposure point); and
4) an exposure route (e.g., inhalation of contaminated dust) at the exposure point.

The exposure assessment process will include the following actions:

- analyze the probable fate and transport of compounds for both the present and the future uses;
- identify the human populations in the area, typical activities that would influence exposure, and sensitive population subgroups;
- identify potential exposure pathways under current and future land use conditions;
- develop exposure scenarios for each identified pathway and select those scenarios that are plausible and that can be quantitatively evaluated;
- identify scenarios assuming both existing and potential future uses; and
- identify the exposure parameters to be used in assessing the risk for all scenarios.

Appropriate exposure scenarios will be identified for the site including a residential scenario. Other scenarios which could potentially be considered include commercial/industrial, and/or recreational. Factors to be examined in the pathway and receptor identification process will include:

- Location of contaminant source;
- Local topography;
- Meteorology;
- Local geohydrology/surface water hydrology;
- Surrounding land use;
- Local water use;
- Prediction of contaminant migration; and
- Persistence and mobility of migrating contaminants.

For each migration pathway and for current and future conditions, receptors will be identified and characterized. Potential receptors will be defined by the appropriate exposure scenarios.

Toxicity Assessment

In accordance with EPA's risk assessment guidelines, the projected concentrations of indicator chemicals at exposure points will be compared with ARARs to judge the degree and extent of risk to public health and the environment (including plants, animals, and ecosystems). Because many ARARs do not exist for certain media (such as soils) nor are all ARARs necessarily health based, this comparison is not sufficient in itself to satisfy the requirements of the risk assessment process. Moreover, receptors may be exposed to contaminants from more than one medium so that their total dose might exceed Reference Doses (RfDs) or the dose might result in an excess cancer risk for noncarcinogenic health effects, (greater than 1 in 1,000,000). Nevertheless, the comparison with standards and criteria is useful in defining the exceedance of institutional requirements. Aside from the ARARs listed in Table 2-13, the following criteria will be examined:

- drinking water health advisories;
- ambient water quality criteria for protection of human health;
- Center for Disease Control and Agency for Toxic Substances and Disease Registry soil advisories; and
- National Ambient Air Quality Standards.

Critical toxicity values (i.e., numerical values derived from dose-response information for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity reference values from EPA's Integrated Risk Information System (IRIS) will be used in preference to other EPA reference values.

A summary of any toxicological studies performed will be provided for target chemicals in the baseline risk assessment. The quality of these studies and their usefulness in estimating human health risks will be described. A more detailed explanation of the toxic effects of target chemicals will be provided in the appendices to the human health risk assessment and the environmental evaluation. Toxicity reference values will also be summarized. For the human health risk assessment, this will include a brief description of the studies upon which selected reference values were based, the uncertainty factors used to calculate RfDs, and the EPA weight-of-evidence classification for carcinogens. For those chemicals without EPA toxicity reference values, a literature search, including computer data bases, will be conducted for selected compounds. A toxicity value will then if possible, be derived from this information. EPA will be consulted regarding the appropriateness of the data and the methodologies to be used in deriving reference values. Uncertainties regarding the toxicity assessment will be discussed.

Three different types of critical toxicity values will be used:

- the acceptable daily intake for subchronic exposure (AIS);
- the acceptable intake for chronic exposure (AIC); and
- the carcinogenic potency factor (for carcinogenic chemicals only).

Risk Characterization

Risk characterization involves integrating exposure assumptions and toxicity information to quantitatively estimate the risk of adverse health effects. Risk characterization will be performed in accordance with EPA guidance. A quantitative risk estimate will be performed for all contaminants. To assess the potential adverse health effects associated with access to the site, the potential level of human exposure to the selected chemicals must be determined. Intakes of exposed populations will be calculated separately for all appropriate pathways of exposure to chemicals. Then for each population-at-risk, the total intake by each route of exposure will be calculated by adding the intakes from each pathway. Total oral, inhalation, and dermal exposures will be estimated separately. Because short-term (subchronic) exposures to relatively high concentrations of chemicals may cause different effects than those caused by long-term (chronic) exposures to lower concentrations, two intake levels will be calculated for each route of exposure to each chemical, i.e., a subchronic daily intake (SDI) and a chronic daily intake (CDI).

An uncertainty analysis will be performed to identify and evaluate non-site and site specific factors that may produce uncertainty in the risk assessment, such as assumptions inherent in the development of toxicological endpoints (potency factors, reference doses). Moreover, site-specific factors which may produce uncertainty will also be discussed.

Risk will be quantified by comparison of contaminant intakes at exposure points to quantitative criteria for protection of human health. The risk assessment portion will include examination of scientific literature to identify daily acceptable intakes of contaminants. Quantitative risk estimates will be made if data are available.

The results of the baseline risk assessment will be used to define and evaluate the remedial alternatives during the FS.

4.1.6.2 Environmental Evaluation

The objective of the environmental evaluation for Operable Unit No. 1 is to determine if the contaminants have caused or are causing any adverse environmental impact. The data to be collected will be utilized to determine the bio-availability and toxicity of the 881 Hillside Area.

The environmental evaluation will be conducted per guidance provided in the "Risk Assessment Guidance for Superfund", Volume II, Environmental Evaluation Manual (U. S. EPA, 1989d) as part of the 881 Hillside Area Phase III RI. The scope of the investigation will include the collection of vegetation, small mammals, arthropods, and aquatic life for determining if bio-accumulation is occurring. The radioecology study, (Rocky Flats Plant Radioecology and Airborne Pathway Summary Report (Rockwell International, 1986f), the Final Environmental Impact Statement (U.S. DOE, 1980), the soils and surface water chemical data, and biological parameters collected during this environmental evaluation will be utilized to assess both the current and future ecological impacts from Operable Unit No. 1.

Field and laboratory activities will be necessary to determine what effect contaminants at the 881 Hillside Area are having on the area's flora and fauna. These activities may include field assessments, toxicity testing, and biomarkers.

Aquatic and terrestrial field surveys will provide detailed assessments of ecological effects. Field surveys for aquatic invertebrates in Woman Creek and terrestrial organisms found within the 881 Hillside Area will be conducted in order to determine if these organisms have been adversely affected by contaminants at this site. The aquatic survey will include relative abundance, species richness, community organization, and biomass. The upper reaches of Woman Creek will serve as a "control" for comparison with results from the site survey. The terrestrial survey will estimate numbers of resident species, determine sex and age ratios, and estimate mortality. These results will be compared to the radioecology report findings.

Toxicity tests will be conducted for the aquatic and terrestrial systems if the surveys indicate an impact. The toxicity of environmental media can be estimated using two approaches: a chemistry-based approach or toxicity-based approach. The chemistry-based approach will first be applied where chemical analyses of water, air, soil, or sediment will be compared to literature criteria to estimate toxicity. If this analysis fails to explain the contaminant impact on the biota, the toxicity based approach will be used. The toxicity-based approach involves the measurements of a biological effect associated with exposure to complex mixtures. For this study, toxicity testing will include acute and chronic toxicity methods for aqueous samples.

The concept of biomarkers is that selected endpoints (such as population-ecosystem density, diversity, or nutrient cycling) which are measured in individual organisms are typically comprised of biochemical or physiological responses that can provide sensitive indices of exposure or sublethal stress. The most direct biomarker to assess exposure is to measure tissue residues which is a key component of bio-accumulation. Biomarkers for sublethal stress include histopathology, determination of skeletal abnormalities, measurement of gas exchange in plants and other various measurements (i.e. enzymes). For this evaluation, toxicological endpoints for indicator or target species will be chosen based on a review of available laboratory toxicity tests providing quantitative data for species of concern, when available. In the absence of toxicological indices for the target species, toxicological endpoints will be derived using safety factors that reflect interspecies extrapolation, acute-to-chronic extrapolations, and added protection for endangered and/or threatened species. Procedures to be used for the field and laboratory activities are presented in the "Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (U.S. EPA, 1989c).

In presenting the conclusions of the environmental evaluation for the 881 Hillside Area, the degree of success in meeting the overall objective of the evaluation will be discussed. Each conclusion will be presented along with items of evidence which would support or fail to support the conclusions and the uncertainty accompanying that conclusion. Any factors that limited or prevented development of definitive conclusions will also be described. Information will be provided to indicate the degree of confidence in the data that was used to assess the site and its contaminants.

4.1.7 Task 7 - Treatability Studies/Pilot Testing

This task includes efforts to prepare and conduct pilot and bench-scale treatability studies, and/or review data from recently conducted testing. These activities will serve to determine the operability, reliability, cost-effectiveness, and overall implementability of a particular remedial alternative. A comprehensive plan for treatability studies designed for remediation of waste sources, soils, and water at all operable units at Rocky Flats will be prepared and submitted to the regulatory agencies in July 1990 in accordance with the draft IAG schedule. This section briefly discusses some of the work that has been conducted, is in progress, or is planned as part of this task. The treatability studies/pilot testing to be conducted or reviewed that are germane to the 881 Hillside Area focus on removal of metals and organic compounds from water.

These processes include Metal Recovery Agent, ferrite adsorption, and granular activated carbon adsorption for removal of uranium. Other treatability studies that have been conducted previously for the 881 Hillside Area include granular activated carbon and UV/peroxide oxidation for organic removal. Review of the performance of the interim action treatment system will provide valuable "pilot scale" performance information on UV/peroxide as well as ion exchange and activated alumina.

Metal Adsorption on MRA

A biomass material called Metal Recovery Agent (MRA) has been developed by Advanced Mineral Technologies (AMT) of Golden, Colorado. According to AMT, this material can be used to remove metals from water. Laboratory- and pilot-scale testing and full-scale systems have proven that MRA is reliable at high metal concentrations. However, testing is necessary to determine the effectiveness of MRA in removing low concentrations of radionuclides from water. The potential benefits of this technology are:

- radionuclide removal would be accomplished without having to retreat the water or significantly change the pH;
- the MRA material can potentially be regenerated at Rocky Flats; and
- the possibility that all metal removal from ground water can be accomplished using one process.

Metal Adsorption on Activated Carbon

This study is intended to determine if radionuclides in contaminated ground water can be adsorbed onto granular activated carbon (GAC). Positive test results would enable GAC to be considered for removing volatile organic compounds and radioactive metals from ground water. Subsequently, GAC may be tested to determine its efficiency in removing non-radioactive metals from ground water. An additional benefit of this study is that it will determine the extent of radionuclide loading on carbon. If it is determined that radionuclides significantly load onto carbon, subsequent evaluations of GAC to remove volatile organics from ground water must include the cost of either an on-site GAC regeneration facility or the cost of shipping the loaded GAC to the Nevada Test Site for disposal.

Column Test (Ferrite) for Radionuclide Removal

A proven technology previously used at Rocky Flats for removing high levels of plutonium from process waste and uranium from water is treatment with ferrite (magnetite). The process requires ferrite to be added to a contaminated solution. With the pH in the 11 to 13 range, radionuclides adsorb to the ferrite. A flocculating agent is added to the slurry to improve settling and separation. The sludge settles to the bottom of the vessel, and is then removed and disposed, ferrite and all. The clean effluent remains. In this study, radionuclide contaminated water at a high pH is passed through a column filled with ferrite to determine the efficiency of radionuclide removal. The use of ferrite in a column will significantly reduce the amount of waste that must ultimately be handled. Once the ferrite is loaded with radionuclides, the column can be backflushed with a mild acid to remove the radionuclides, allowing reuse of the ferrite in the column. The concentrated metal contaminated stream would require further processing prior to disposal.

4.1.8 Task 8 - Remedial Investigation Report

A Draft Phase III RI Report will be prepared to consolidate and summarize the data obtained during Phases I, II, and III RI field work. This report will:

- Describe in detail the field activities which serve as a basis for the RI report. This will include any deviations from the work plan which occurred during implementation of the field investigation.
- Thoroughly discuss site physical conditions. This discussion will include surface features, meteorology, surface water hydrology, surficial geology, ground-water hydrology, demography and land use, and ecology.
- Present site characterization results discussing the nature and extent of contamination. The media to be addressed will include contaminant sources, soils, ground water, surface water, air, and biota.
- Discuss contaminant fate and transport. This discussion will include potential migration routes, contaminant persistence, and contaminant migration.

- Present a baseline risk assessment. The risk assessment will include human health and environmental evaluations.
- Present a summary and conclusions.

4.2 FEASIBILITY STUDY TASKS

A draft final FS is planned for the 881 Hillside Area to evaluate remedial alternatives for clean up of contaminated soils, ground water, and surface water. Results of the Phase III RI and baseline risk assessment will indicate to what extent other remedial action is necessary for Operable Unit No. 1.

As discussed in Section 2.5, the draft FS was incomplete in addressing the full extent and nature of contamination. The organization of the draft report is also not consistent with the latest EPA guidance [Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U.S. EPA, 1988a)]. This section describes the tasks to be performed that conform with the EPA guidance.

The FS process occurs in two phases. The first phase consists of developing and screening remedial alternatives, and the second phase includes a detailed analysis of alternatives (U.S. EPA, 1988a). Each of these two phases are discussed in the following sections.

4.2.1 Task 9 - Remedial Alternatives Development and Screening

The goal of this task is to identify and screen remedial alternatives. The work consists of four parts:

- Identifying remedial technologies;
- Screening remedial technologies;
- Developing remedial alternatives; and
- Screening remedial alternatives.

General response actions that may prove appropriate at the site were identified in Section 2.5. These general response actions were identified in order to determine data gaps to be addressed in RI activities. For each response action, potentially applicable remedial technologies were identified. These are also presented in Section 2.5. As the Phase III RI progresses, additional potentially applicable technologies may be determined.

During screening, the broad expanse of potentially applicable technology types will be narrowed by eliminating those technologies that are not technically implementable. Based on contaminant concentrations and other site-specific information contained in the Phase III RI, non-implementable technology types will be screened and eliminated from further consideration.

Technology process options will then be screened in order to select a representative process option for each technology type that is technically implementable. Process options are compared and eliminated based on their effectiveness relative to other processes within the same technology type. The screening is based on the volume of media to be treated, achievement of remediation goals, potential impacts on human health and the environment, and the proven performance and reliability of the option considering the contaminants and site characteristics. In addition to effectiveness, the process options will also be evaluated based on administrative feasibility and relative cost.

To develop alternatives, general response actions and the process options that are representative of the various technology types for each medium will be combined to form alternatives for the operable unit. In general, more than one response action is applicable to each medium. Response actions and process options will be assembled based primarily on medium-specific considerations and implementability. Descriptions of each alternative will be developed for inclusion in the FS report.

During alternative screening, the developed alternatives will be evaluated to ensure that they protect human health and welfare and the environment from each potential pathway of concern at the operable unit. Treatment rates will be identified, and the size and configuration of on-site extraction and treatment systems or containment structures will be developed. The time frame in which treatment, containment or removal goals can be achieved will be determined. Lastly, spatial requirements for treatment units, containment structures, staging of construction materials, excavated wastes, etc. will be determined. If there are off-site actions such as surface water discharge, a regulatory review will be conducted to determine permit and compliance requirements.

Alternatives will then be further defined to provide sufficient information to differentiate among alternatives with respect to effectiveness, implementability and cost. Each alternative will be evaluated to determine its effectiveness in protecting human health and the environment, and in reducing toxicity, mobility or volume of hazardous wastes or contaminated media. As a consequence of reducing the toxicity, mobility or volume, the inherent threats or risks associated with wastes are decreased.

Implementability is a measure of both the technical and administrative feasibility of constructing, operating and maintaining a remedial action alternative. It is used during screening to evaluate the combinations of process options with respect to the site-specific conditions. Technical feasibility refers to the ability to construct, reliably operate and comply with action-specific (technology-specific) requirements in order to complete the remedial action. Administrative feasibility refers to the ability to obtain required permits and approvals; to obtain the necessary services and capacity for treatment, storage and disposal of hazardous wastes; and to obtain essential equipment and technical expertise.

Cost estimates for screening will be derived from cost curves, generic unit costs, vendor information, conventional cost estimating guides and prior estimates made for Rocky Flats and similar sites, with modifications made for Rocky Flats Plant conditions. Absolute cost accuracy is not necessary. The cost estimates for the alternatives however, will have the same relative accuracy for comparison and screening. The cost estimating procedures used during screening are similar to those that will be used during the later detailed alternatives analysis.

The later detailed analysis however, will receive more in-depth and detailed cost estimates of the components of each alternative. The screening cost estimates will include capital, operating, and maintenance costs. The operating and maintenance costs will be calculated for the lifetime of the treatment unit operation at the site. Present worth cost analysis will be used for alternatives in order to make the costs for the various alternatives comparable.

Alternatives with the most favorable results from the composite evaluation will be retained for further scrutiny during the detailed analysis. Not more than ten alternatives will be retained for detailed analysis (including containment and no action). At that time, it may be determined that additional site-specific information or technology-specific treatability studies are necessary for an objective detailed analysis. Also, it will be necessary to identify and verify the action-specific ARARs that each respective alternative will be required to meet.

4.2.2 Task 10 - Detailed Analysis of Remedial Alternatives

The detailed analysis is not a decision-making process, but it is the process of analyzing and comparing relevant information in order to select a remedial action. Each alternative will be assessed against nine evaluation criteria, and the assessments will be compared to identify the key tradeoffs among the alternatives. Assessment against the nine evaluation criteria is necessary for the FS and the subsequent Record of Decision (ROD)/Corrective Action Decision (CAD) to comply with the requirements of CERCLA/RCRA.

4.2.2.1 Alternative Analysis Against Nine Evaluation Criteria

Overall Protection of Human Health and the Environment

The alternatives will be individually analyzed to determine if the alternative provides adequate protection of human health and the environment. The protectiveness evaluation focuses on how the risks posed by each pathway are being eliminated, reduced or controlled by treatment, engineering or institutional measures.

Compliance with ARARs

Each alternative will be analyzed to determine whether it will comply with all state and federal ARARs that have been identified. The analysis will address compliance with chemical-specific, location-specific and action-specific ARARs. If an alternative will not comply with an ARAR, the FS report will present the basis for justifying a waiver.

Long-Term Effectiveness and Permanence

This criterion assesses the risks that are left at the site after the response objectives have been met. The risks associated with any remaining untreated wastes or treatment residuals will be evaluated. For each alternative, the magnitude of the residual risk, and the reliability and adequacy of the controls used to manage untreated wastes and treatment residuals will be addressed.

Reduction of Toxicity, Mobility or Volume Through Treatment

This criterion evaluates the statutory preference of selecting remedial actions that permanently reduce toxicity, mobility, or volume of the hazardous materials. Factors evaluated for each alternative will include the proposed treatment process and the materials treated; the quantity of materials to be treated or destroyed, and how the primary hazardous threat will be addressed; the estimated degree of the reduction in toxicity, mobility or volume that will be achieved; the extent to which the treatment will be irreversible; the type and quantity of treatment residuals that will remain following treatment; and a determination if the alternative will comply with the statutory preference for treatment.

Short-Term Effectiveness

Short-term effectiveness refers to the effects an alternative may have during the construction and implementation phases until the cleanup objectives have been achieved.

Alternatives will be evaluated to determine the effects on human health and the environment during implementation. Each alternative will be assessed against the following factors: protection of the community and workers during the remedial action; environmental impacts; and the time required to achieve the remedial action objectives.

Implementability

This criterion assesses the technical and administrative feasibility of implementing an alternative, and the availability of the necessary services and materials. The following factors will be analyzed during the implementability assessment: the technical feasibility of construction and operation; the reliability of the technology; the practicability of employing additional remedial actions; the ability to monitor the effectiveness of the remedial action; administrative coordination with other offices and agencies; the availability of adequate off-site hazardous (or mixed) waste treatment, storage and disposal; and the availability of equipment, expertise and other services and materials.

Costs

An in-depth cost estimate will be conducted, and if necessary, a cost sensitivity analysis will be prepared to evaluate costing assumptions. Capital costs include direct construction costs and indirect non-construction costs and overhead costs. Operating and maintenance costs are incurred after construction in order to operate the remedial action on a continuous basis until the remedial action objectives have been achieved. FS cost estimates are expected to be within an accuracy range of minus 30 percent to plus 50 percent. If this accuracy cannot be achieved, it will be stated in the FS report.

A cost sensitivity analysis may be conducted to determine the effect that specific cost assumptions have on the total estimated cost of an alternative. The cost assumptions will be based on site-specific data, technological operating data, etc. although the assumptions will be subject to varying degrees of uncertainty depending on the accuracy of the data.

State Acceptance

This criterion addresses the state's administrative and technical issues and concerns with each of the alternatives.

Community Acceptance

Community acceptance addresses the public's concerns and issues with each of the alternatives.

4.2.2.2 Comparison of Alternatives

The FS report will contain a narrative discussion of each alternative's evaluation against the nine criteria. The narrative will describe how each alternative addresses the technical treatability issues, long-term and short-term effectiveness, costs, protection of human health and the environment, compliance with ARARs, etc. Once the alternatives have been described, a comparative analysis will be conducted to evaluate the relative performance of each alternative. The relative advantages and disadvantages of each alternative with respect to the other alternatives will be determined in order to assess the key tradeoffs that must be made in selecting a remedial action. A candidate alternative must generally attain the primary objectives of compliance with ARARs and overall protection of human health and the environment in order for it to be eligible for selection as the remedial action. A narrative discussion of the alternatives comparison describing the tradeoffs, and the benefits and detriments of each alternative in comparison to the others will be included in the FS report.

Following completion of the FS process, the results of the detailed alternatives comparison and risk management will be used as the rationale for selecting a preferred alternative and a remedial action. Although the purpose of the FS report and process is not to select a remedial action, it will present and evaluate the alternatives in sufficient detail in order to objectively consider all significant issues and select a feasible, cost-effective and defensible remedial action.

4.2.3 Task 11 - Feasibility Study Report

The FS Report will present the results of the feasibility study. The report will include sections describing site background; nature and extent of problem; results of the RI; risk assessment and environmental evaluation; identification, screening and detailed evaluation of remedial alternatives, and the recommended remedial actions. This task includes development of a Draft Final FS, a revised Draft Final FS that incorporates EPA and CDH comments, and preparation of a Final FS that incorporates public comments.

5.0 PHASE III RI FIELD SAMPLING PLAN

The overall objectives of the Phase III RI are source characterization and better definition of the nature and extent of soils, alluvial ground-water, and surface water contamination. Within these broad objectives, site specific data objectives and needs have been identified in Section 3.0. The purpose of this section is to provide a detailed field sampling plan which will satisfy these data objectives and needs.

5.1 SOURCE CHARACTERIZATION

Further source characterization is required for sites within Operable Unit No. 1. Boreholes will be drilled into SWMUs to characterize any waste materials remaining in place and to assess the maximum contaminant concentrations in soils directly beneath the sites. In addition, ground-water monitoring wells will be installed adjacent to some of the boreholes to characterize ground-water quality directly beneath the sites. This section discusses those wells and boreholes which will be drilled for source characterization. Wells to be drilled outside of SWMUs for characterizing the extent of contamination are discussed in Section 5.1.2. All proposed Phase III RI boreholes and wells are shown on Figure 5-1. Drilling, sampling, and well installation will follow the Rocky Flats Plant ER Program SOP.

Boreholes to be drilled into SWMUs will extend from the ground surface to the base of weathered bedrock. Continuous samples will be collected for geologic descriptions for the entire borehole depth. From this core, discrete samples will be submitted for laboratory chemical analyses every two feet from the ground surface to the water table. In addition, a discrete sample will be collected for chemical analysis at the water table. Core from saturated surficial materials will not be submitted to the laboratory, as the presence of water in this zone will affect interpretation of chemical results. In order to prevent alluvial ground water from affecting weathered bedrock samples, surface casing will be grouted into the borehole through surficial materials. Subsequent to grout hardening, the borehole will then be advanced through weathered bedrock with continuous sampling. Discrete samples from the core will be submitted to the laboratory for chemical analysis from two feet immediately below the casing and every four feet thereafter to the base of weathering. To further characterize bedrock immediately beneath the sites, in-situ packer tests will be performed in the weathered bedrock where drilling conditions allow.

Alluvial ground-water monitoring wells will be installed adjacent to some boreholes to characterize ground-water quality directly beneath SWMUs. In addition, bedrock wells will be installed adjacent to boreholes where weathered sandstone is encountered within source areas to evaluate the potential downward migration of contaminants. Wells will be drilled, sampled, and completed in accordance with the Rocky Flats ER Program SOP. Source characterization well locations are discussed in the following sections.

5.1.1 Sample Locations

5.1.1.1 Oil Sludge Pit Site (SWMU Ref. No. 102)

The location of SWMU 102 has been revised from that shown in the Phase II RI report (Rockwell International, 1988a) based on further review of historical aerial photographs. Specifically, the Oil Sludge Pit Site appears on 1955 and 1962 aerial photos. Also evident on the 1955 photos is seepage from the pit as shown on Figure 5-1. The pit was covered after its use (Rockwell International, 1987c), and it is no longer visible on 1959 aerial photographs. Additional soil and ground-water sampling are needed within, surrounding, and downgradient of SWMU 102 to document its location and to evaluate the nature and extent of potential contamination downgradient of the site.

Two borings are proposed within this site to document its presence and location (Figure 5-1). Boreholes BH01 and BH02 will be drilled and sampled within the revised site location to identify the nature and maximum concentration of any contaminants associated with

SWMU 102. Colluvial monitor well MW01 will be completed adjacent to BH01 to monitor ground-water quality directly beneath the site.

In order to assess the nature and extent of soil and ground-water contamination downgradient of the Oil Sludge Pit Site, five boreholes are proposed in the area of staining directly south of the site. Boreholes BH03, BH04, and BH05 will all be drilled and sampled within the area of seepage from SWMU 102 identified on 1955 aerial photographs. A colluvial monitor well (MW02) will also be installed adjacent to borehole BH04 to assess ground-water flow directions and quality in this area. Boreholes BH06 and BH07 are proposed downgradient of the seepage area to assess the extent of soil contamination. As the proposed french drain at the 881 Hillside is upgradient of the apparent seepage from SWMU 102, boreholes BH03, BH05, and BH06 will be drilled and sampled during the current drilling program to evaluate the proposed french drain alignment (Section 5.3).

Additional boreholes are proposed within and surrounding the former retention pond along Woman Creek to characterize soil and ground-water conditions in this area. Two boreholes (BH08/MW33 and BH09) will be drilled within the former pond location, and two alluvial monitor wells (MW03 and MW33) are proposed in and south of the former pond. These wells will serve to characterize the Woman Creek valley fill alluvial ground water downgradient of SWMU 102.

5.1.1.2 Chemical Burial Site (SWMU Ref. No. 103)

No boreholes or monitor wells were installed directly within SWMU 103 during previous investigations. Additional drilling and sampling are thus needed to characterize this site. Three boreholes (BH10, BH11, and BH12) are proposed within the SWMU to identify the nature and maximum concentration of potential contaminants. A colluvial monitor well (MW04) will be completed adjacent to BH10 to characterize ground water directly beneath the site, and colluvial monitor well MW05 will characterize ground-water quality immediately downgradient of the site.

5.1.1.3 Liquid Dumping Site (SWMU Ref. No. 104)

A site east of Building 881 was reportedly used for disposal of unknown liquids and empty drums prior to 1969 (U. S. DOE, 1986). The site was located as shown on Figure 5-1 by Rockwell International (1987c) based on 1965 aerial photographs. Although further review of these photographs indicates this site may be a shadow on the photo. Based on their description, it is suspected that SWMUs 103 and 104 are actually the same site. However, the Phase III RI will include sampling and analysis of soils at the originally reported Liquid Dumping Site location to document its presence or lack thereof. Two boreholes will be drilled within this reported SWMU location (BH13 and BH14).

5.1.1.4 Out-of-Service Fuel Oil Tanks (SWMU Ref. Nos. 105.1 and 105.2)

These two sites were effectively taken out of service in 1976, when they were filled with asbestos containing materials and then with concrete. As the materials inside the tanks are solidified, they do not pose an environmental hazard. In addition, the tanks tested tight in 1973 when they were pressure tested. However, in order to document the lack of soil contamination associated with these tanks, four adjacent boreholes are proposed (BH15, BH16, BH17, and BH18).

5.1.1.5 Outfall Site (SWMU Ref. No. 106)

The Outfall Site consists of a six inch diameter vitrified clay pipe which is an overflow line from the sanitary sewer sump in Building 887. Discharge from this pipe was observed in December 1977 (Rockwell International, 1987c); however, subsequent discharges have not been noted. Phase III RI activities at this site will include verifying the connection between the outfall pipe and Building 887 (original reports of the discharge indicated this was a clean-up pipe for an overflow line from the Building 881 cooling tower) as well as soil and ground-water sampling downgradient of the outfall.

In order to verify the source of SWMU 106, water will be introduced to the outfall pipe from the Building 887 sewer sump, and the outfall on the hillside will be observed for discharge. If the water is observed at the outfall, then the Building 887 sewer sump is the source of SWMU 106, and measures will be taken to contain any future discharges. If the Building 887 sewer sump is not the source of SWMU 106, further investigation of this site will be needed.

Soil and ground-water contamination may exist downgradient of the Outfall Site due to previous releases from the site. In order to characterize any contamination, two boreholes (BH19 and BH20) will be drilled and sampled immediately below the outfall. A colluvial monitor well (MW06) will be installed adjacent to borehole BH19 to evaluate ground-water quality beneath the outfall.

5.1.1.6 Hillside Oil Leak Site (SWMU Ref. No. 107)

The Hillside Oil Leak Site was originally designated as a SWMU because of an oil leak at this location in May, 1973 (Rockwell International, 1987c). It was later discovered that the oil had emerged through the Building 881 footing drain outfall, and a ditch and skimming pond were built to contain the oil (Owen and Steward, 1973). The skimming pond is still present; although, no oil has been observed in the outfall since 1973 (Rockwell International, 1987c). During the 881 Hillside Phase II RI, volatile organic compounds were detected in the outfall pipe and in the skimming pond (Rockwell International, 1988a).

There are thus two issues associated with the Hillside Oil Leak Site:

1) the nature and extent of soil and ground-water contamination potentially resulting from the original hillside oil leak; and

2) the source of volatile organic contaminants currently found in the Building 881 footing drain outfall.

Two footing drains extend south from the Building 881 foundation (Figure 1-6). The western line joins the eastern line near the southeast corner of Building 885. This line then runs south where it daylights into the skimming pond. The first step of this source investigation will consist of determining which of the two footing drains is the source of volatile organics at the footing drain outfall. This will be accomplished by sampling the effluent in each footing drain line through a manhole located just south of their junction. The line (or lines) responsible for contaminants at the outfall will then be sampled at clean-out points (if accessible) along its length to further isolate the contaminant source.

Soil, ground-water, and surface water samples will be collected within SWMU 107 in order to characterize the nature and extent of contamination. Soil samples will be collected from boreholes within the skimming pond. Boreholes BH21 and BH22 are proposed and will be advanced to refusal using a hand auger. Routine surface water sampling will continue at stations SW-44 and SW-45.

5.1.1.7 Multiple Solvent Spill Sites (SWMU Ref. Nos. 119.1 and 119.2)

SWMUs 119.1 and 119.2 were used from 1967 to 1972 for barrel storage. Although the exact types and quantities of wastes stored at these sites are unknown, the barrels likely contained cutting oil wastes and solvents. Spills and leaks from these drums likely occurred during the period of drum storage. Barrel storage locations within the sites are shown on Figure 5-1.

<u>SWMU 119.1</u>

A total of ten boreholes are proposed within the western barrel storage area to characterize the nature and extent of soil contamination associated with this site. Boreholes BH23 through BH32 will be drilled and sampled within the drum storage areas as shown on Figure 5-1. In addition, colluvial monitor wells MW07, MW08, MW09, MW10, and MW11 will be installed to evaluate ground-water quality beneath the site and at the downgradient edge of the site, as data from wells 48-87, 10-74, and 6-87 indicate multiple upgradient sources.

SWMU 119.2

Seven boreholes (BH33 through BH39) are proposed within the barrel storage areas of SWMU 119.2 to evaluate the nature and extent of potential soil contamination. Monitor wells MW12 and MW13 will serve to monitor ground-water quality at the site's east-southeast downgradient edge.

5.1.1.8 Radioactive Site No. 1-800 Area (SWMU Ref. No. 130)

This site was used to dispose of soil contaminated with low levels of plutonium between 1969 and 1972. Radionuclides were not above background levels in soil samples collected from this site during the Phase I and Phase II RIs. However, additional soil samples will be collected from eight boreholes during the Phase III RI to verify this finding. Boreholes BH40 through BH47 will be drilled and sampled through the site to assess the nature and extent of soil contamination. In addition, colluvial monitor wells MW14, MW15, and MW16 will be installed adjacent to boreholes BH45, BH46, and BH47, respectively, to monitor water quality at the downgradient edge of this site.

5.1.1.9 Sanitary Waste Line Leak Site (SWMU Ref. No. 145)

SWMU 145 is an area at the southeast corner of Building 881 where the sanitary sewer leaked in January 1981. As no hazardous or radioactive constituents were released to the environment by this leak and the leak was repaired, no further investigation of this site is necessary.

5.1.1.10 Building 885 Drum Storage Site (SWMU Ref. No. 177)

Building 885 is currently used for satellite collection and 90-day accumulation of RCRA regulated wastes. A plan for soil sampling at this site is provided in the RCRA Interim Status Closure Plan which is appended to the revised Post-Closure Care Permit Application for hazardous and radioactive mixed wastes at the Rocky Flats Plant (Rockwell International, 1988c).

5.1.2 SAMPLE ANALYSIS

5.1.2.1 Chemical Analysis of Soil Samples

Soil samples will be collected from boreholes within and adjacent to SWMUs to characterize sources. All samples will be analyzed for the chemical parameters listed in Table 5-1 following CLP methods or the methods specified in the QA/QC plan. These parameters are essentially the same as those analyzed in the Phase I RI except that oil and grease and RCRA characteristics are eliminated. Oil and grease have not proven useful in determining extent of soil contamination, and RCRA hazardous waste characteristics have been within acceptable limits. Total petroleum hydrocarbons were added to the analyte list for SWMUs 102 and 105 where fuel oil is a potential contaminant. With a few exceptions, the TCL list for organics and the TAL list for inorganics are the same as the previously used HSL list for organics and inorganics.

5.1.2.2 Soil Blanks

Use of soil blanks is not necessarily standard protocol in the collection of soil samples for subsequent chemical analysis. In the Phase I and II RIs, methylene chloride, acetone, and phthalates appear to be contaminants in samples that were introduced through sample handling or sample analysis. Soil blanks were not used in the previous investigation but appear

TABLE 5-1

PHASE III RI
SOIL AND WASTE SAMPLING PARAMETERS

METALS

Target Analyte List - Metals

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Vanadium
- Zinc

Other Metals

- Molybdenum
- Cesium
- Strontium
- Lithium
- Tin

INORGANICS

- pH
- Nitrate
- Percent Solids
- Sulfides

ORGANICS

Target Compound List - Volatiles

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- total 1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,2-Dichloropropene

TABLE 5-1 (Continued)

PHASE III RI
SOIL AND WASTE SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes
- 1,1-Dichloroethane

Other Organics

- Total petroleum hydrocarbons*

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene

TABLE 5-1 (Continued)

PHASE III RI
SOIL AND WASTE SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (continued)

- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol
- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Pyrene
- Butyl Benzylphthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- alpha-Chlordane
- gamma-Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

TABLE 5-1 (Continued)

PHASE III RI
SOIL AND WASTE SAMPLING PARAMETERS

RADIONUCLIDES	
	Gross Alpha
	Gross Beta
	Uranium 233+234, 235 and 238
	Americium 241
	Plutonium 239+240
	Tritium
	Strontium 90, 89
	Cesium 137

NOTE: * Analytes for SWMUs 102 and 105 only.

Select samples will be analyzed for constituents in 40 CFR 268 Table CCWE and Appendix III as well as organic matter content and BTU content.

necessary to confirm these findings. Procedures for preparation of blanks will be documented in the revised SOPs, due for release in July 1990. An experiment will also be designed to determine the source of phthalate contamination in soil samples. If appropriate, an alternative for sample handling will be implemented to avoid phthalate contamination in the future.

5.2 NATURE AND EXTENT OF CONTAMINATION

In addition to source characterization, the Phase III RI will focus on additional ground-water, surface water, and sediment sampling to further characterize the nature and extent of contamination in each of these media arising from the SWMUs. These sampling programs are outlined in detail below.

5.2.1 Ground Water

5.2.1.1 Monitor Well Locations

Based on data collected during the Phase I and II investigations, volatile organics are present in unconfined ground-water flow systems at the 881 Hillside Area. The extent of contamination is not fully delineated, and additional monitor wells are needed to define the vertical and lateral extent of the organics. Potential major ion, trace metal, and radionuclide impacts to ground water were not well characterized in the Phase II RI report due to the lack of appropriate background ground-water quality data. Presented below are proposed monitoring well locations and rationale to further characterize ground-water flow and quality in the unconfined flow system at the 881 Hillside Area.

Upgradient Wells

Four new alluvial monitoring wells are proposed upgradient of the 881 Hillside Area to characterize the quality of ground water entering the sites. These wells (MW17, MW18, MW19, and MW20) will all be completed in Rocky Flats Alluvium. MW17 and MW18 will be located east and north, respectively, of Building 881, and wells MW19 and MW20 will be located on the Rocky Flats Alluvium terrace north of SWMUs 119.1 and 119.2 (Figure 5-1).

SWMUs 119.1 and 130

Three alluvial and three bedrock wells will be installed downgradient of SWMU 119.1 to further characterize the extent of volatile organics detected in wells 48-87, 10-74, 9-74, and 4-87. Alluvial well MW21 will be located between 9-74 and 4-87 and will be completed in colluvial gravel. Data from the well will serve to further characterize the transport of contaminants found in wells 9-74 and 43-87 to well 4-87. Alluvial wells MW22 and MW23 will further delineate the extent of colluvial saturation and water quality south of SWMUs 119.1 and 130.

Further investigation of the bedrock sandstone at well 5-87BR is also proposed for the Phase III RI, because TDS, strontium, and selenium were elevated during 1989. Three wells (MW24, MW25, and MW26) are proposed for completion in this sandstone (Figure 5-1). As the extent and orientation of the sandstone and the ground-water flow direction within the sandstone are uncertain, these wells will be located in presumably upgradient (west), sidegradient (south), and downgradient (east) directions. Water level data from the wells will then be used to determine ground-water flow directions.

South Interceptor Ditch

In addition to well MW02, three other colluvial monitor wells will be installed along the South Interceptor Ditch. These wells (MW27, MW28, and MW29) will serve to monitor ground-water quality and levels adjacent to the ditch (Figure 5-1), and the resulting data will be used to evaluate the interaction between South Interceptor Ditch surface water and unconfined ground water.

Woman Creek Valley Fill Alluvium

Further characterization of valley fill water quality and the surface water/ground-water interaction are also needed along Woman Creek downgradient of the 881 Hillside Area. Wells MW30, MW31, and MW32, in addition to well MW03, will all be completed in Woman Creek valley fill alluvium (Figure 5-1).

5.2.1.2 Chemical Analysis of Ground-Water Samples

Ground-water samples will be collected from all new and existing monitoring wells at the 881 Hillside Area upon completion of well development. Samples will be analyzed for the parameters listed in Table 5-2 during the first round of sampling after completion of 1990 wells. This parameter list may be reduced in subsequent quarterly sampling events if certain parameter groups are not detected or are not significantly above background levels. Ground-water samples will be analyzed in the field for pH, conductivity, and temperature. With the exception of samples designated for organics, major ions, and tritium analyses, all samples will be filtered and preserved in the field. Organics, major ions, and tritium samples will not be filtered.

5.2.1.3 Hydraulic Testing

In order to further characterize hydraulic conductivity values of geologic materials in the 881 Hillside Area, hydraulic tests will be performed in all newly installed monitor wells subsequent to well development. These tests may be slug tests, bail down-recovery tests, or single hole pumping tests depending on the sustainable flow rate from a given well. Hydraulic test data will be analyzed using a method appropriate to the field test method, and the results will be presented in the RI report. In addition, multi-well pumping and tracer tests will be performed along Woman Creek to further characterize the valley fill alluvium as discussed below.

TABLE 5-2

PHASE III RI
GROUND-WATER SAMPLING PARAMETERS

FIELD PARAMETERS

- pH
- Specific Conductance
- Temperature

INDICATORS

- Total Dissolved Solids
- pH

DISSOLVED METALS

- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc
- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS

- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide
- Fluoride

ORGANICS

- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane
  - total 1,2-Dichloroethene

TABLE 5-2 (Continued)

PHASE III RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol

TABLE 5-2 (Continued)

PHASE III RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (Continued)

- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol
- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Pyrene
- Butyl Benzylphthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- alpha-Chlordane
- gamma-Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

TABLE 5-2 (Continued)

PHASE III RI
GROUND-WATER SAMPLING PARAMETERS

RADIONUCLIDES	
	Gross Alpha
	Gross Beta
	Uranium 233+234, 235, and 238
	Americium 241
	Plutonium 239+240
	Tritium
	Cesium 137
	Strontium 90
	Radium 226, 228

Pumping and Tracer Tests in Woman Creek Valley Alluvium

Pumping and tracer tests will be performed in the Woman Creek Alluvium to develop better estimates of solute travel times. Currently, the hydraulic conductivity and effective porosity are known to estimated accuracies of about a factor of three; the dispersivity is known to an estimated accuracy of about an order of magnitude. In order to measure these parameters in the field (especially the effective porosity) and to account for spatial variability, three pumping and tracer tests will be performed in the Woman Creek Alluvium between the 881 Hillside and Indiana Street. The test locations are shown on Figure 5-2.

Each test will be performed in an array of 15 wellpoints (Figure 5-3). The array has been designed to produce linear flow for the tracer test but will also work for the pumping test. The wellpoints will consist of 1.5-inch diameter stainless steel wellpoints driven into the ground using a drill rig. In order to minimize deviation from vertical while driving the wellpoints, a pilot boring will be made to approximately four feet below ground and the point driven through the hollow stem of the auger. The screens will be five feet long so that the points are screened over the entire saturated thickness. After completion of each test, the wellpoints will be pulled out of the ground and any remaining openings filled with neat cement grout with five percent bentonite. The well points will be re-used in the next tests.

Pumping Test

The pumping test will be performed by pumping Well A (Figure 5-3) at a constant rate for four hours. In general, the Woman Creek alluvium varies in thickness from three to eight feet and the saturated thickness varies from about zero to four feet, although the alluvium can become fully saturated at times. The alluvium is a minimum of seventy-five feet wide and the hydraulic conductivity is approximately 1×10^{-3} cm/s, based on baildown-recovery and slug tests. Preliminary calculations (assuming a saturated thickness of four feet, hydraulic conductivity of 1×10^{-3} cm/s, and a storage coefficient of 0.1) indicate that the Woman Creek

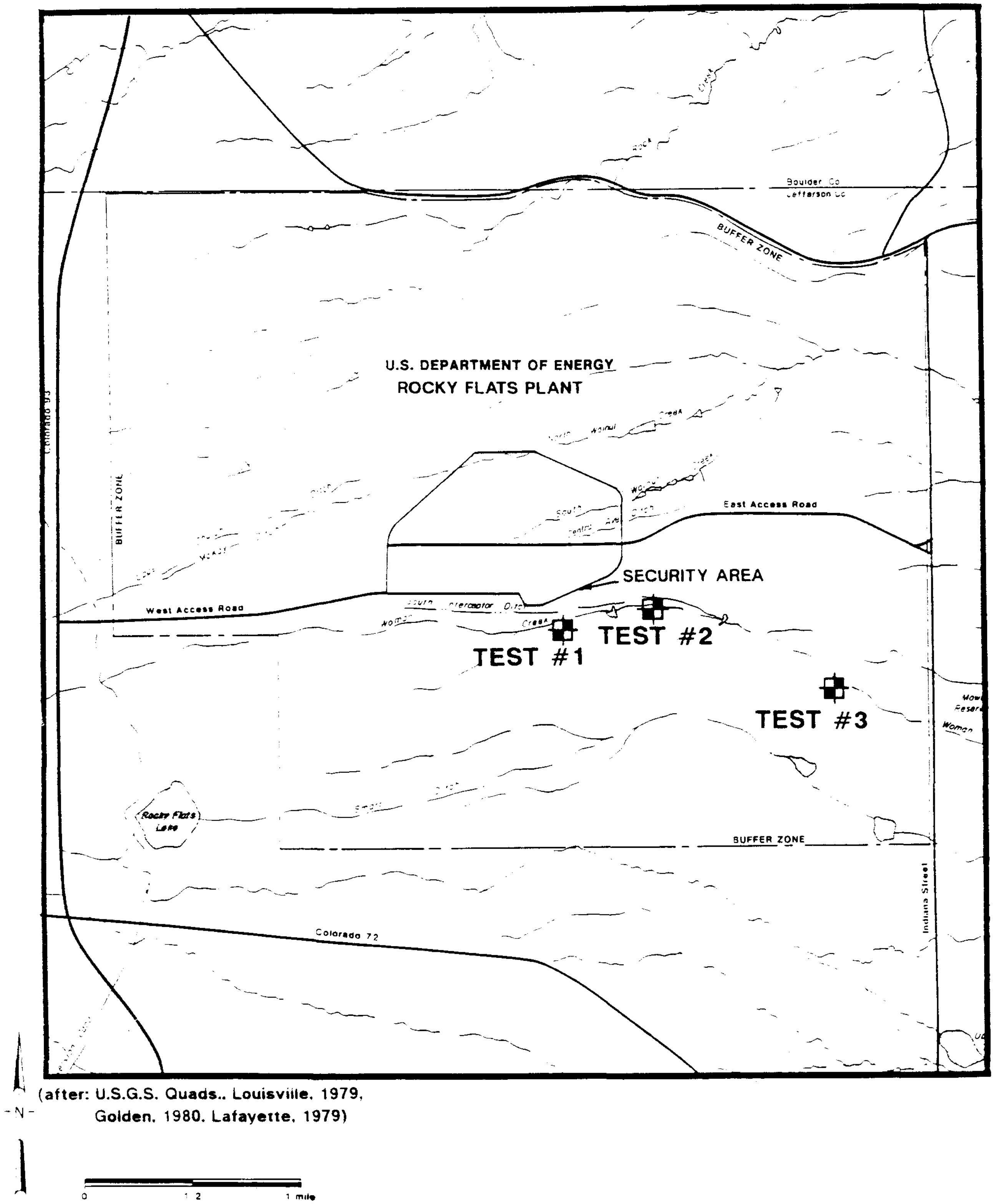


FIGURE 5-2
PUMPING AND TRACER TEST LOCATIONS

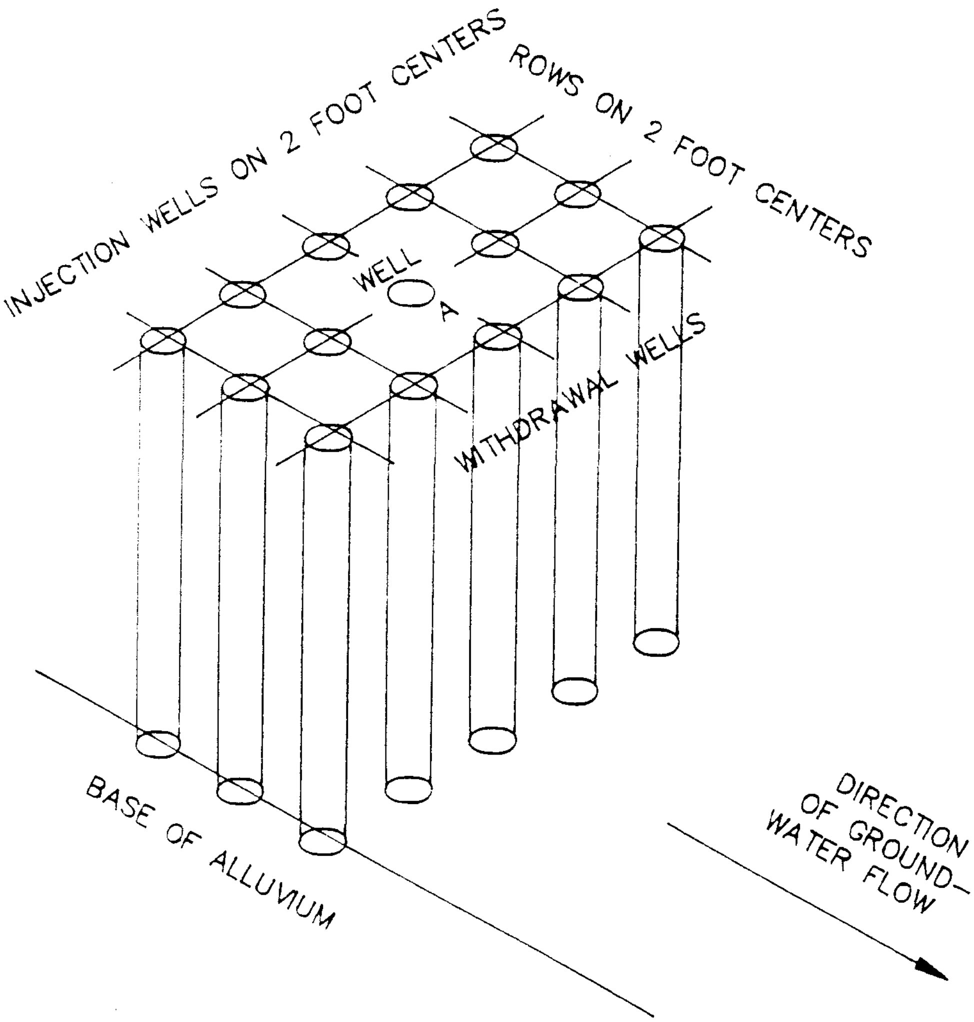


FIGURE 5-3
PUMPING AND TRACER TEST WELL ARRAY

alluvium can sustain a constant discharge of 0.17 gallons per minute (gpm) for the period of pumping with drawdowns ranging from two feet in a fully efficient pumping well to 0.19 feet at a distance of five feet.

The well will be suction-pumped using an electrically operated peristaltic pump. A peristaltic pump is expected to perform well in this application because the suction lift is small (estimated to be no more than ten feet) and because a peristaltic pump can be run at very small, constant flow rates. All produced water will be drummed (41 gallons in four hours) and reinjected into the formation as part of the tracer test. Time-drawdown data during both the pumping and recovery periods will be collected from all of the wells using either depth to water probes or electrical transducers.

The pumping test will be analyzed as a constant rate withdrawal test in unconfined materials to yield hydraulic conductivity and storage coefficient. Delayed yield will be considered, if appropriate. In addition, the efficiency of the well (theoretical drawdown divided by observed drawdown, times 100 percent) will be evaluated for use in the tracer test calculations.

Tracer Test

A linear flow system will be created by injecting water into the five upstream wells and withdrawing water from the five downstream wells. Although two lines of three wells can produce linear flow between the middle wells, two lines of five wells will be used in order to provide greater assurance of linear flow between the middle wells. Water will be supplied to the injection wells and withdrawn from the withdrawal wells (Figure 5-3) using peristaltic pumps controlled by electrical liquid level probes. Water levels in both the injection and withdrawal wells will be allowed to fluctuate approximately 0.20 feet and will result in an average head differential of one foot (gradient of 0.25). The water levels will be maintained such that the upstream wells produce a one foot head increase and the downstream wells produce approximately an unchanged head condition. Heads in the formation will be calculated assuming that the well efficiencies are as determined in the pumping test.

Steady linear flow will be created by injecting the ground water withdrawn during the pumping test plus waters withdrawn from the withdrawal wells. It is estimated that each well will require an average steady flow of approximately 0.03 gpm (calculated using the Darcy equation) and that steady linear flow will be achieved in approximately seven hours.

The tracer test will be performed in two phases after linear flow has been achieved. The first phase will inject a non-conductive fluid (distilled water) into the injection wells; the arrival of the injection fluid at the downstream withdrawal wells will be indicated by a reduction of the conductivity of the water. The natural conductivity of the alluvial ground water is approximately 500 to 1,000 micromhos per centimeter and that of distilled water is near zero.

Although there are many other tracers that could be used in this test, distilled water is felt to be the least environmentally damaging and was therefore selected. Releases of adsorbed ions from the solid phase to the distilled water may occur during the course of the test; however, the magnitude of this effect is expected to be small because of the quartzitic and granitic mineralogy of the formation. If adsorbed ions are released, the steady state conductivity at the downstream wells will be somewhat higher than zero; the actual value will be used as the 100 percent concentration for breakthrough and earlier values scaled accordingly. The impact of using a lower concentration tracer will be tested by re-injecting the produced formation fluids (higher conductivity) as a second phase of the test. All water withdrawn during the test will be drummed for this later use. If the lower conductivity water cannot be detected in the withdrawal wells, an alternate test will be designed using Rhodamine WT dye with either a fluorimeter or a spectrofluorometer for quantitative detection.

Time-conductivity data will be collected from all of the wells using dedicated conductivity probes. Complete mixing of the water in the injection and withdrawal wells will be achieved with a recirculation system to avoid chemical stratification in the wellbore. Conductivity will be measured in flow-through conductivity cells uphole. Water will be added or withdrawn from the recirculation system on each well through solenoid valves controlled by the liquid level probes. It is estimated that the 50 percent concentration will arrive at the withdrawal well approximately 400 minutes after injection begins (using an effective porosity of 0.1, hydraulic conductivity of 1×10^{-3} cm/s, gradient of 0.25 and a dispersivity of 0.1 feet). The test will continue until the conductivity in the middle withdrawal well stabilizes.

During the second phase of the tracer test, the water collected during the first phase will be injected into the injection wells (approximately 150 gallons) without withdrawal from the withdrawal wells. The intent of the second phase is to evaluate the impact of using a lower concentration tracer during the first phase. The test will be performed as described above and the dispersivity recalculated for comparison with the original determination. During this phase, linear flow will be maintained but gradients may vary somewhat during the test because downstream withdrawal will not occur, possibly resulting in unsteady flow. Again, the water in the withdrawal wells will be mixed using the recirculation system to prevent stratification in the wellbore. The test will continue until the conductivity of the water in the middle withdrawal well stabilizes.

The time-conductivity data will be analyzed using the equation for dispersion in a semi-infinite medium in a unidirectional flow field (Ogata, 1970). The time at which the 50 percent concentration arrives at the downstream withdrawal well will be used to calculate the effective porosity (given that the gradient is known from the test conditions and the hydraulic conductivity is known from the pumping test). The dispersivity will be found by curve matching to the time-conductivity data.

These calculations will yield a vertically averaged longitudinal dispersivity appropriate for use with a vertically averaged hydraulic conductivity. The effects of hydraulic conductivity variations will be included in the calculated dispersivity. It is recognized that spatial variation of both the hydraulic conductivity and the transport parameters is likely; therefore, three tests will be performed at different locations in the alluvium. It is also recognized that dispersivity is a scale dependent parameter and that the dispersivity developed in these tests will only be appropriate for finely gridded analytical models (nodal spacings on the order of 4 to 40 feet). However, it is anticipated that the effective porosity values developed will be applicable for calculation of nondispersive ground-water flow velocities.

5.2.2 Surface Water and Sediments

5.2.2.1 Sample Locations

Ten surface water stations were established south of the 881 Hillside Area in the Woman Creek drainage during the 1986 and 1987 investigations. Surface water sampling at these stations is currently conducted on a monthly basis and will continue through 1990. Figure 2-17 presents surface water monitoring locations in the area, and Table 5-3 presents the surface water stations to be sampled during the Phase III RI.

Bedload sediment samples were taken in October 1989 at stations along Woman Creek and the South Interceptor Ditch. The resulting data should suffice as confirmatory information regarding the concentrations of volatile organics, metals, other inorganics, and radionuclides in the sediments. However, quarterly sediment sampling is continuing at the Plant, and bedload sediment samples will be collected from the 881 Hillside Area. For the Phase III RI, physical characteristics of the sediments (background and "downgradient") and the spatial distribution of the metal concentrations will be examined to assess the adequacy of the background sediment geochemical characterization and thus whether metals are contaminants in the sediments at the 881 Hillside Area.

TABLE 5-3

SURFACE WATER SAMPLING STATIONS

SW-31

SW-35

SW-44

SW-45

SW-46

SW-66

SW-67

SW-68

SW-69

SW-70

5.2.2.2 Chemical Analysis of Surface Water and Sediment Samples

Laboratory analyses of surface water samples will consist of the parameters listed in Table 5-4, and sediments will be analyzed for the parameters listed in Table 5-1. Surface water samples will be analyzed in the field for pH, conductivity, temperature, and dissolved oxygen. All samples requiring filtration will be filtered in the field, and all samples will be preserved in the field. Surface water sampling and stream flow measurements will follow the procedures described in the Rocky Flats ER Program SOP.

5.3 EVALUATION OF PROPOSED INTERIM REMEDIAL ACTION

An interim remedial action is proposed at the 881 Hillside Area to collect, treat, and discharge contaminated alluvial ground water. Alluvial ground water will be collected by a french drain across the hillside and pumped to a water treatment plant at the top of the hillside. A geotechnical and geochemical soils investigation is being performed at the 881 Hillside Area in order to evaluate the site characteristics along the proposed french drain alignment, a possible french drain extension, and associated influent and effluent lines (Figure 5-4). This investigation is currently in progress and will be completed prior to the Phase III RI field activities.

5.3.1 Borehole Locations

A series of 38 borings on 100 foot centers or less will be taken along the entire length of the influent/effluent lines and the french drain alignment. The following information will be obtained from these borings:

- Accurate lithologic logs utilizing the Unified Soil Classification system;
- Geotechnical soil and bedrock samples and testing (in-situ and laboratory) to assist in the design of the french drain system and evaluate the slope stability of the 881 Hillside;

TABLE 5-4

PHASE III RI
SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen

INDICATORS

- Total Dissolved Solids
- Total Suspended Solids
- pH

DISSOLVED AND TOTAL METALS

- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc

- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS

- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide
- Fluoride
- Phosphate

ORGANICS

- Oil and Grease
- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone

TABLE 5-4 (Continued)

PHASE III RI
SURFACE WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- total 1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2 Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

RADIONUCLIDES

- Gross Alpha (Filtered)
- Gross Beta (Filtered)
- Uranium 233+ 234, 235, and 238
  (Filtered and Unfiltered)
- Americium 241 (Filtered and Unfiltered)
- Plutonium 239+240 (Filtered and Unfiltered)
- Tritium (Unfiltered)
- Cesium 137
- Radium 226, 228
- Strontium 90

- Samples for chemical analyses that will add to the 881 Hillside database, will determine health and safety requirements for construction activities, and determine disposal requirements for excavated soils; and
- Geologic data for generating geologic cross sections.

Twenty-six of these boreholes will be drilled along the proposed french drain alignment. The objectives of these boreholes are to determine:

- Bedrock lithology including location of subcropping sandstone units;
- Depth to bedrock;
- Appropriate level of health and safety protection for french drain construction;
- Appropriate disposition of excavated soils;
- Geotechnical characteristics of area soils;
- Hydraulic conductivities of each five foot depth interval in bedrock and discrete conductivities of any subcropping sandstones that are encountered;
- Appropriateness of proposed french drain location; and
- Chemical characteristics of soils along the alignment.

Four of the 26 french drain alignment boreholes will be completed as piezometers (Figure 5-4). These piezometers will serve to characterize the extent of saturation downgradient of SWMU 119.2 which will evaluate the need for extending the french drain to include this area.

In addition, four piezometers will be installed at one location along the french drain during the Phase III RI to assess the effectiveness of the drain (Figure 5-1). PZ01 will be completed in weathered claystone adjacent to wells MW21 (colluvium completion) and MW 25 (weathered sandstone completion). Together, these wells and piezometers will serve to characterize the extent of saturation in various geologic units upgradient of the french drain. Piezometers PZ02, PZ03, and PZ04 will be completed in colluvium, weathered claystone, and weathered sandstone (if present), respectively, to characterize the extent of saturation downgradient of the french drain. Water levels in these wells and piezometers will be monitored both prior and subsequent to construction of the french drain in order to observe changes caused by its operation.

Twelve boreholes will be drilled along the proposed influent/effluent pipeline alignment. Select samples from these boreholes will be submitted to the laboratory for geotechnical analyses (Section 5.3.3) and one set of samples from each borehole will be submitted for geochemical analysis. General objectives of these boreholes are to determine:

- Bedrock lithologies including the identification of any sandstone units;
- Depth to bedrock;
- Appropriate level of health and safety protection for construction;
- Appropriate disposition of excavated soils; and
- Geotechnical characteristics of area soils.

5.3.2 Chemical Analysis of Soil Samples

Boreholes along the proposed french drain alignment will be continuously sampled for lithologic descriptions from ground surface to bedrock. Discrete soil samples will be collected for volatile organic analysis every two feet, and composite samples for metal, inorganic, semi-volatile organic, pesticide, PCB, and radionuclide analyses will be collected every four feet. Soil samples will be analyzed for the parameters listed in Table 5-1.

One set of samples from each of the influent/effluent boreholes will be submitted for the analytes listed in Table 5-1. A continuous sample will be obtained from zero to five feet in depth. A discrete soil sample from the five feet will be submitted for volatile organic analysis, and the remaining material will be homogenized and submitted for the other analytes. The anticipated depth of the pipeline is four to five feet. This sampling and analysis scheme will enable the health and safety protocol for pipeline construction to be established, and will determine the ultimate disposal option for excavated soil.

5.3.3 Geotechnical Testing of Soil Samples

Select geotechnical soil samples along the proposed french drain alignment will be obtained from boreholes using Shelby tubes or in accordance with standard penetration test procedures (ASTM D-1586). An estimated 40 samples will be submitted to the laboratory for geotechnical testing. Geotechnical tests will include moisture content, unit weight, Atterberg limits, and grain size distribution to further characterize geologic materials at the 881 Hillside. In order to evaluate slope stability, consolidated undrained triaxial shear tests and/or direct shear tests will be conducted on approximately ten soil samples. Flexible wall, triaxial cell back pressure preparations tests will also be conducted on select samples.

Boreholes along the proposed influent/effluent pipeline alignment will be drilled from ground surface to the top of bedrock. Soil samples will be collected every five feet in accordance with standard penetration test procedures (ASTM D-1586). An estimated 125 soil samples will be collected from these boreholes, and samples representative of site conditions will be submitted to the laboratory for geotechnical testing. Physical analyses will include moisture content, unit weight, Atterberg limits, grain size distribution, consolidation tests, and compression tests. Additionally, four to five consolidated undrained triaxial shear or direct shear test will be conducted on select samples.

5.3.4 Geotechnical Testing of Bedrock Samples

Approximately 18 feet of bedrock will be cored in each of the proposed french drain alignment borings. Select geotechnical tests will be conducted on sections of core. These tests will include back pressure constant head permeability, direct shear, unconsolidated undrained and consolidated undrained triaxial shear, moisture and density and grain size analysis. If sandstone is encountered, the coring will be advanced to include a minimum of five continuous feet of claystone. Borings performed adjacent to those in which sandstone was encountered shall be advanced to a depth necessary to identify and characterize the sandstone unit.

5.3.5 In-situ Packer Testing

In order to further characterize the hydraulic conductivity of weathered bedrock at the 881 Hillside Area, in-situ packer tests will be performed in boreholes drilled along the proposed french drain alignment. Packer tests will be performed in the bedrock portion of boreholes using a double packer arrangement. These tests will be conducted at depths of five, ten, and fifteen feet below the alluvium/bedrock contact. If sandstone units are encountered discrete packer tests will be conducted over their entire thickness. At least one five foot packer test will be conducted within claystone beneath encountered sandstone units.

6.0 REFERENCES

Dames and Moore, 1981, Geologic and Seismologic Investigations for Rocky Flats Plant, Contract DE-AC04-80A110890.

DRCOG, 1989, "DRCOG Makes 1989 Estimates of Metro Population and Households." Denver Regional Council of Governments, September 1989.

Hodgin, C.R., 1983, A Receptor-Based Technique for Determining Impacts of Wind-Resuspended Particulates: RFP-3362, Rockwell International, Rocky Flats Plant, Golden, Colorado.

Hodgin, C.R., 1984, A Model for Asymmetrical Plume Growth and Dispersion in Complex Terrain, Fourth Joint Conference on Applications of Air Pollution Meteorology, Portland, Oregon, American Meteorological Society.

Hurr, R.T., 1976, Hydrology of a Nuclear-Processing Plant Site, Rocky Flats, Jefferson County, Colorado; U.S. Geological Survey Open-File Report 76-268.

Hydro-Search, Inc., 1985, Hydrogeologic Characterization of the Rocky Flats Plant, Golden, Colorado; Project No. 1520, December 9, 55 p.

Hydro-Search, Inc., 1986, Electromagnetic Survey, Rocky Flats Plant, Golden, Colorado; Project No. 106G05502.

Illsley, C. T., 1978, Briefing on Buried Trenches: Rockwell International, unnumbered internal letter to M. V. Werkema, December 19, 1978.

Malde, H.E., 1955, Surficial Geology of Louisville Quadrangle, Colorado, U.S. Geological Survey Bulletin 996-E, pp. 217-257.

Ogata, A., 1970, Theory of Dispersion in a Granular Medium, U.S. Geological Survey Professional Paper 411-I.

Owen, J.B. and L.M. Steward, 1973, Environmental Inventory - A Historical Summation of Environmental Incidents Affecting Soils at or Near the U.S. AEC Rocky Flats Plant: Dow Chemical Company, Rocky Flats Division.

Paine, D., 1980, "Plutonium in Rocky Flats Freshwater Systems": Transuranic Elements in the Environment, Wayne C. Hanson, editor, U.S. Department of Energy, DOE/TIC-22800.

Post, P., 1989, Personal Communication: U.S. Department of Agricultural Statistics Service, November, 1989.

Putzier, E. A., 1970, A Summary of On-Site Radioactive Waste Disposal: Dow Chemical Company unnumbered report, April 22, 1970.

Robson, S.G., 1983, Hydraulic Characteristics of the Principal Bedrock Aquifers in the Denver Basin, Colorado, U.S. Geological Survey Hydrologic Investigations Atlas HA659.

Robson, S.G., J.C. Romero, and S. Zawistowski, 1981a, Geologic Structure, Hydrology, and Water Quality of the Arapahoe Aquifer in the Denver Basin, Colorado: U.S. Geological Survey Atlas HA-647.

Robson, S.G., A. Wacinski, S. Zawistowski, and J.C. Romero, 1981b, Geologic Structure, Hydrology, and Water Quality of the Laramie-Fox Hills Aquifer in the Denver Basin, Colorado: U.S. Geological Survey Hydrologic Atlas HA-650.

Rockwell International, 1975, Annual Environmental Monitoring Report: January-December 1974; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-74.

Rockwell International, 1976, Annual Environmental Monitoring Report: January-December 1975; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-75.

Rockwell International, 1977, Annual Environmental Monitoring Report: January-December 1976; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-76.

Rockwell International, 1978, Annual Environmental Monitoring Report: January-December 1977; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-77.

Rockwell International, 1979, Annual Environmental Monitoring Report: January-December 1978; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-78.

Rockwell International, 1980, Annual Environmental Monitoring Report: January-December 1979; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-79.

Rockwell International, 1981, Annual Environmental Monitoring Report: January-December 1980; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-80.

Rockwell International, 1982, Annual Environmental Monitoring Report: January-December 1981; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-81.

Rockwell International, 1983, Annual Environmental Monitoring Report: January-December 1982; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-82.

Rockwell International, 1984, Annual Environmental Monitoring Report: January-December 1983; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-83.

Rockwell International, 1985, Annual Environmental Monitoring Report: January-December 1984; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-84.

Rockwell International, 1986a, Geological and Hydrological Data Summary, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, July 21, 58 p.

Rockwell International, 1986b, Annual Environmental Monitoring Report; January-December 1985; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-85.

Rockwell International, 1986c, Draft Work Plan, Geological and Hydrological Site Characterization; U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

Rockwell International, 1986d, Draft Project Operations Plan, Geological and Hydrological Site Characterization; U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

Rockwell International, 1986e, Resource Conservation and Recovery Act Part B - Post-Closure Care Permit Application for U.S. DOE Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes; U.S. Department of Energy, unnumbered report.

Rockwell International, 1986f, Rocky Flats Plant Radioecology and Airborne Pathway Summary Report; Rockwell International, Rocky Flats Plant, Golden, Colorado, unnumbered report.

Rockwell International, 1987a, Draft Remedial Investigation Report for High Priority Sites 881 Hillside Area), U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

Rockwell International, 1987b, Annual Environmental Monitoring Report: January-December 1986; Rockwell International, Rocky Flats Plant, Golden, Colorado, report RFP-ENV-86.

Rockwell International, 1987c, Resource Conservation and Recovery Act Part B - Operating Permit Application for U.S. DOE Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes, Revision 1; U.S. Department of Energy, unnumbered report.

Rockwell International, 1988a, Draft Final Remedial Investigation Report for the High Priority Sites (881 Hillside), U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

Rockwell International, 1988b, Feasibility Study Report for the High Priority Sites (881 Hillside), U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado.

Rockwell International, 1988c, Resource Conservation and Recovery Act Post-Closure Care Permit Application for U. S. DOE Rocky Flats Plant Hazardous and Radioactive Mixed Wastes: Permit No. CO7890010526, October 5, 1988.

Rockwell International, 1989a, 881 Hillside Remedial Investigation and Feasibility Study Response to EPA Comments, February 24, 1989.

Rockwell International, 1989b, Background Hydrogeochemical Characterization and Monitoring Plan, Environmental Restoration Plan, Rocky Flats Plant, January 1989.

Rockwell International, 1989c, Background Geochemical Characterization Report, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, December 15, 1989

Rockwell International, 1989d, Quality Assurance/Quality Control Plan: Environmental Restoration Program, Rocky Flats Plant, January 1989.

Scott, G.R., 1960, "Quaternary Sequence East of the Front Range Near Denver, Colorado", in Guide to Geology of Colorado, by Weimer, R.J. and J.D. Haun (eds.); Geological Society of America, Rocky Mountain Association Geologists, Colorado Scientific Society, pp. 206-211.

Scott, G.R., 1963, Quaternary Geology and Geomorphic History of the Kassler Quadrangle, Colorado; U.S. Geologic Survey Prof. Paper 421-A.

Scott, G.R., 1965, "Nonglacial Quaternary Geology of the Southern and Middle Rocky Mountains" in The Quaternary of the United States; Princeton University Press pp. 243-254.

Scott, G.R., 1970, Quaternary Faulting and Potential Earthquakes in East- Central Colorado: U.S. Geological Survey, Prof. Paper 700-C, pp. C11-C18.

Scott, G.R., 1972, Geologic Map of the Morrison Quadrangle, Jefferson County, Colorado, U.S. Geological Survey Miscellaneous Geologic Inventory Map I-790-A.

Scott, G.R., 1975, Cenozoic Surfaces and Deposits in the Southern Rocky Mountains in Cenozoic History of the Southern Rocky Mountains, Curtis, B.F. (ed.); Geological Society of America Memoir 144, pp. 227-248.

Spencer, F.D., 1961, Bedrock Geology of the Louisville Quadrangle, Colorado, U.S. Geological Survey Geologic Quadrangle Map GQ-151.

Tracer Research Inc., 1986, Shallow Soil Gas Investigation of the Rocky Flats Plant, Golden, Colorado.

U.S. DOE, 1980, Final Environmental Impact Statement: Rocky Flats Plant Site, Golden, Jefferson County, Colorado, Volumes 1, 2, and 3; U.S. Department of Energy Report; Washington, D.C., DOE/EIS-0064.

U.S. DOE, 1986, Comprehensive Environmental Assessment and Response Program Phase 1: Draft Installation Assessment Rocky Flats Plant; U.S. Department of Energy, unnumbered draft report.

U.S. DOE, 1987a, Comprehensive Environmental Assessment and Response Program, Phase 2: Rocky Flats Plant, Draft Site-Specific Monitoring Plan, U.S. Department of Energy.

U.S. DOE, 1987b, Comprehensive Environmental Assessment and Response Program, Phase 2: Rocky Flats Plant, Draft Installation Generic Monitoring Plan, U.S. Department of Energy.

U.S. DOE, 1990a, Final Proposed Interim Measures/Interim Remedial Action Plan and Decision Document, 881 Hillside Area, High Priority Sites, U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, January 1990.

U.S. DOE, 1990b, Environmental Assessment for 881 Hillside (High Priority Sites) Interim Remedial Action, U.S. Department of Energy, January 1990.

U.S. EPA, 1985, Endangerment Assessment Handbook.

U.S. EPA, 1987, Data Quality Objectives for Remedial Response Activities; EPA/54-/G-87/003,OSWER Directive 9355.0-7B, March 1987.

U.S. EPA, 1988a, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA Interim Final: EPA/540/G-89/004, OSWER Directive 9355.3.01, October 1988.

U.S. EPA, 1988b, Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses; Technical Directive Document No. HQ8410-01, Contract No. 68-01-6699.

U.S. EPA, 1988c, Superfund Exposure Assessment Manual, EPA/540/1-88/001.

U.S. EPA, 1988d, CERCLA Compliance with Other Laws Manual. OSWER Directive No. 9234.1-01.

U.S. EPA, 1989a, Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A, Interim Final, OSWER Directive 9285.7-01a.

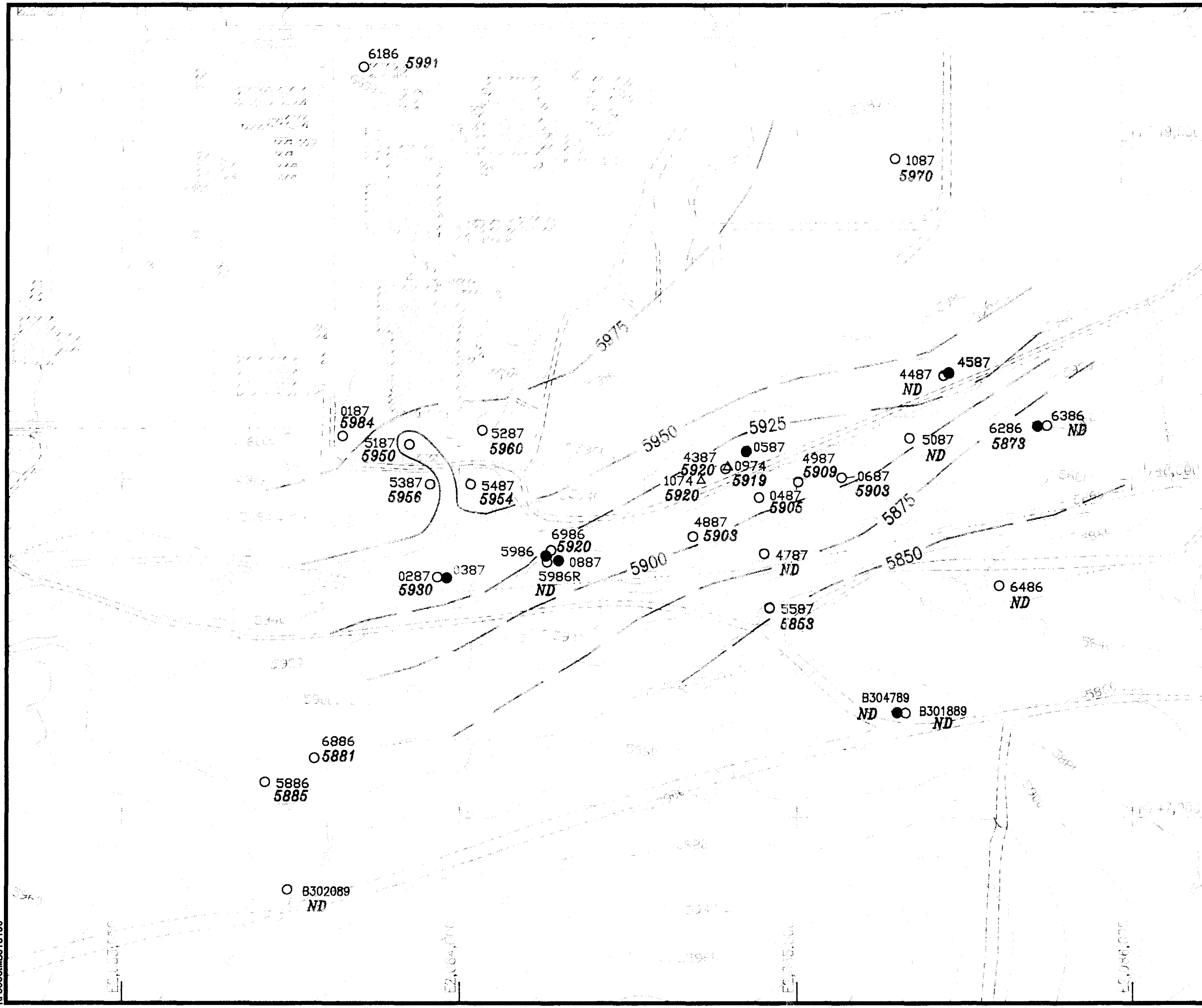
U.S. EPA, 1989b, Exposure Factors Handbook, EPA/600/8-89/043.

U.S. EPA, 1989c, Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference, EPA/600/3-89/013.

U.S. EPA, 1989d, Environmental Evaluation Manual, Interim Final,EPA/540/1-89/001.

Van Horn, R., 1972, Surficial and Bedrock Geologic Map of the Golden Quadrangle, Jefferson County, Colorado; U.S. Geologic Survey Misc. Geol. Field Inv. Map I-761-A.

Van Horn, R., 1976, Geology of the Golden Quadrangle, Colorado: U.S. Geological Survey Prof. Paper 872, 116 p.



EXPLANATION

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

5851 Potentiometric Surface Elevation (feet above mean sea level)

5920 Line of Equal Potentiometric Surface Elevation (feet above sea level – dashed where approximately located)

ND No Data – Well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

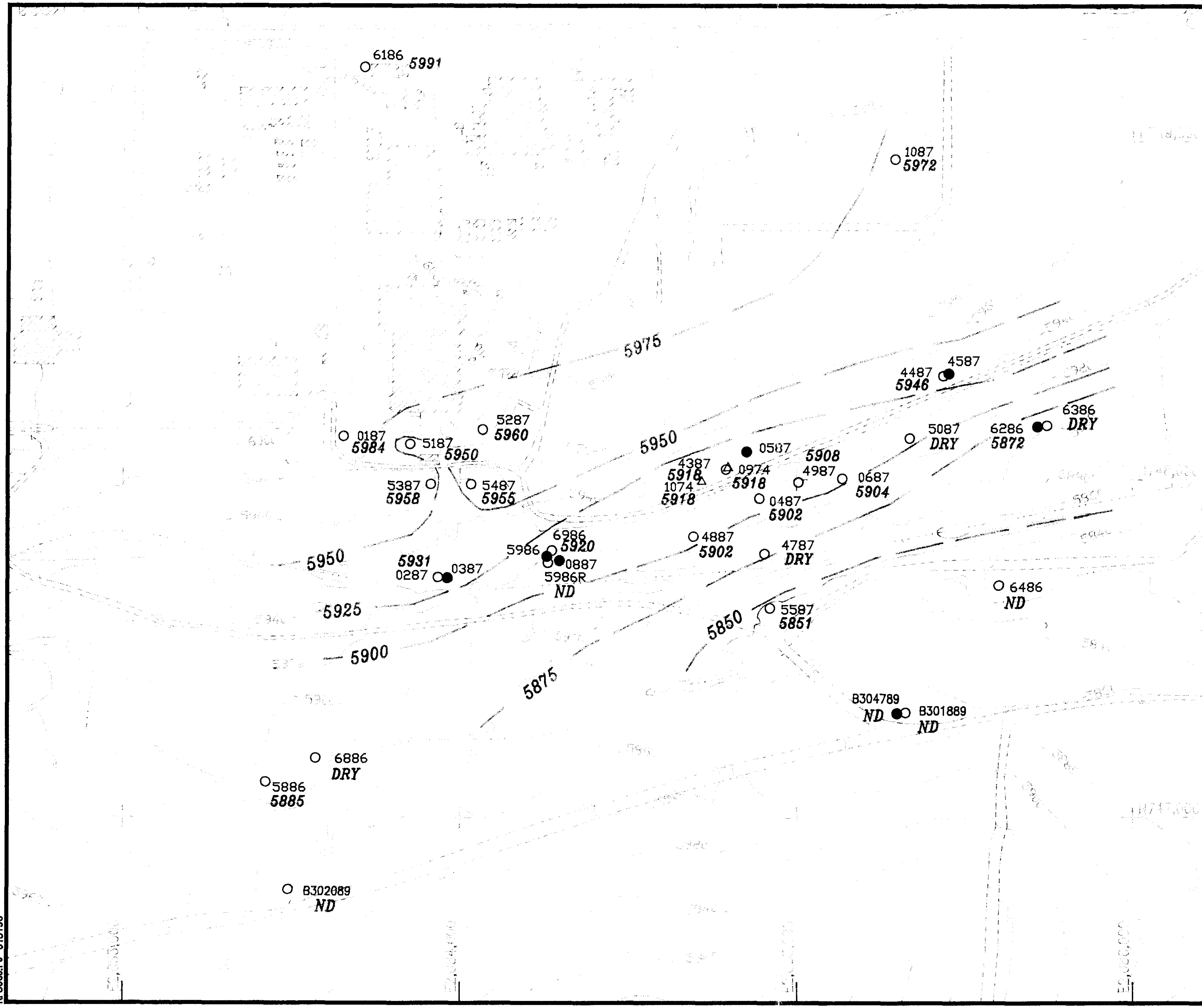
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-4

POTENTIOMETRIC SURFACE OF UNCONFINED GROUND-WATER FLOW SYSTEM
May 1988

February, 1990

RF300G.MB013190



EXPLANATION

B301889	○	Alluvial Monitoring Well
B304789	●	Bedrock Monitoring Well
0271	△	Pre-1986 Well
5851		Potentiometric Surface Elevation (feet above mean sea level)
5920		Line of Equal Potentiometric Surface Elevation (feet above sea level – dashed where approximately located)
ND		No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

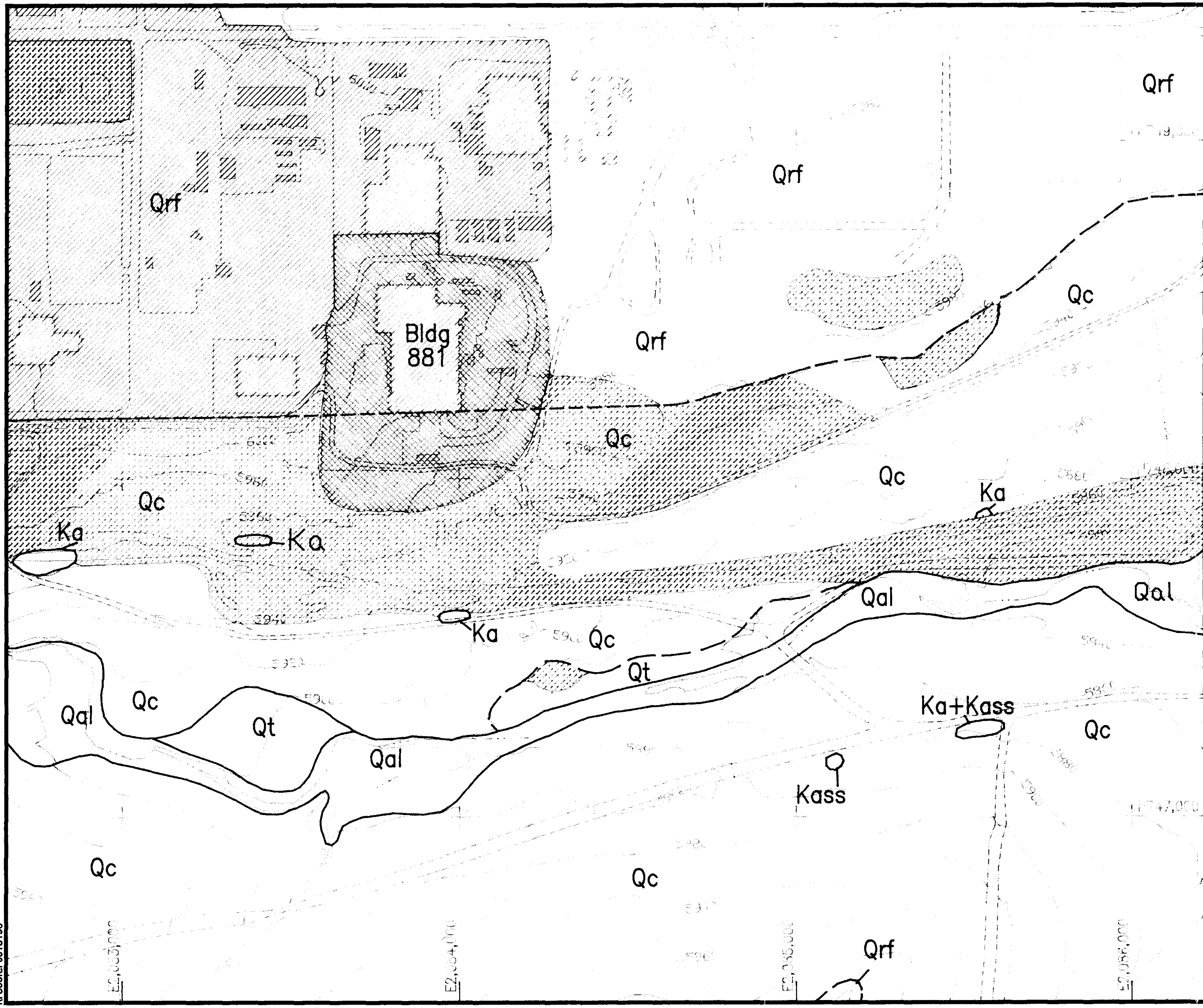
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-3

POTENTIOMETRIC SURFACE OF UNCONFINED GROUND-WATER FLOW SYSTEM
January 1988

February, 1990

RF3001.PJ-013190



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

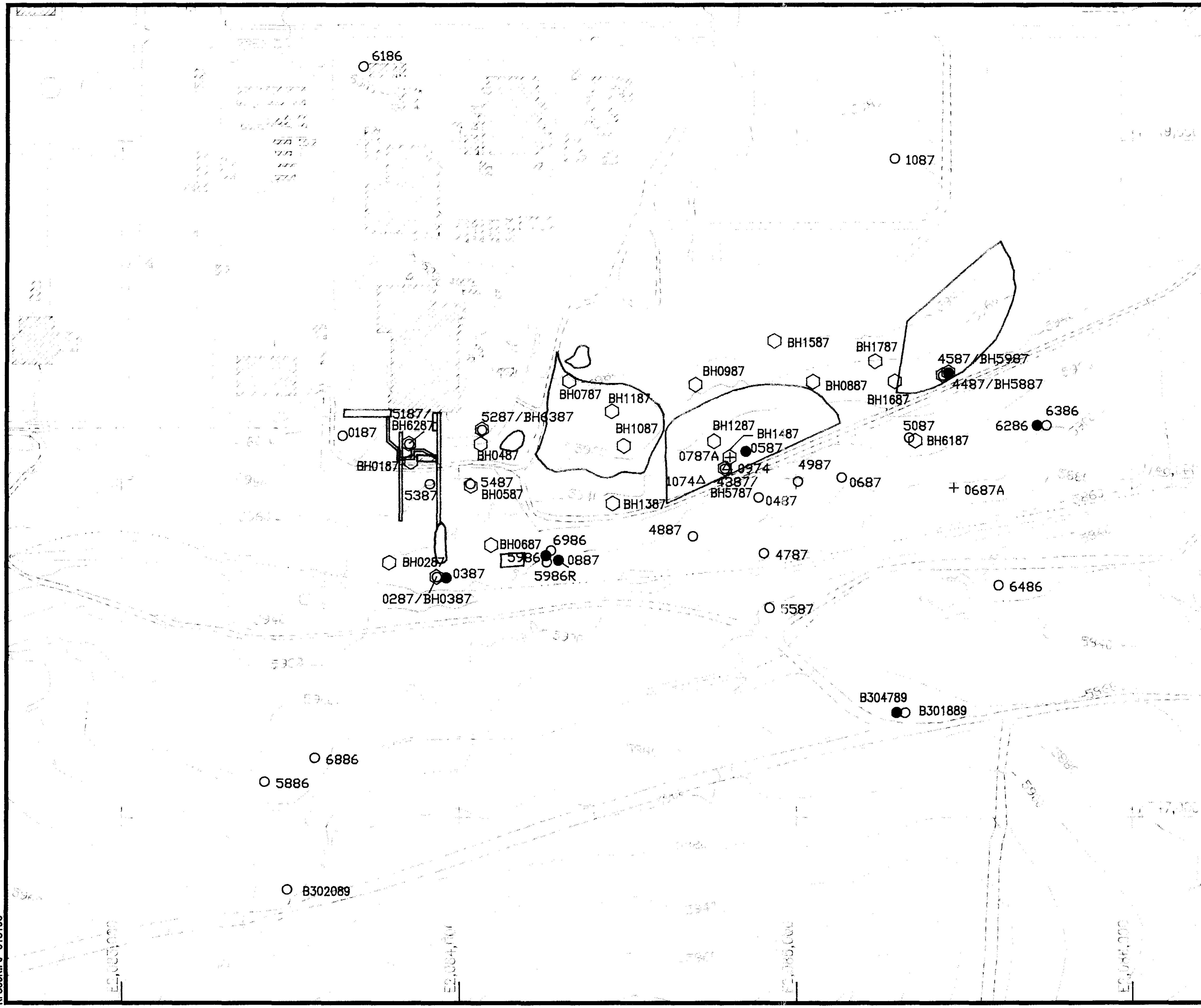
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-2

SURFICIAL GEOLOGY

February, 1990

RF300K.PJ013190



EXPLANATION

		Solid Waste Management Unit (SWMU)
B301889	O	Alluvial Monitoring Well
B304789	●	Bedrock Monitoring Well
0271	△	Pre-1986 Well
1187A	+	Abandoned Hole
BH0987	⬡	Borehole

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

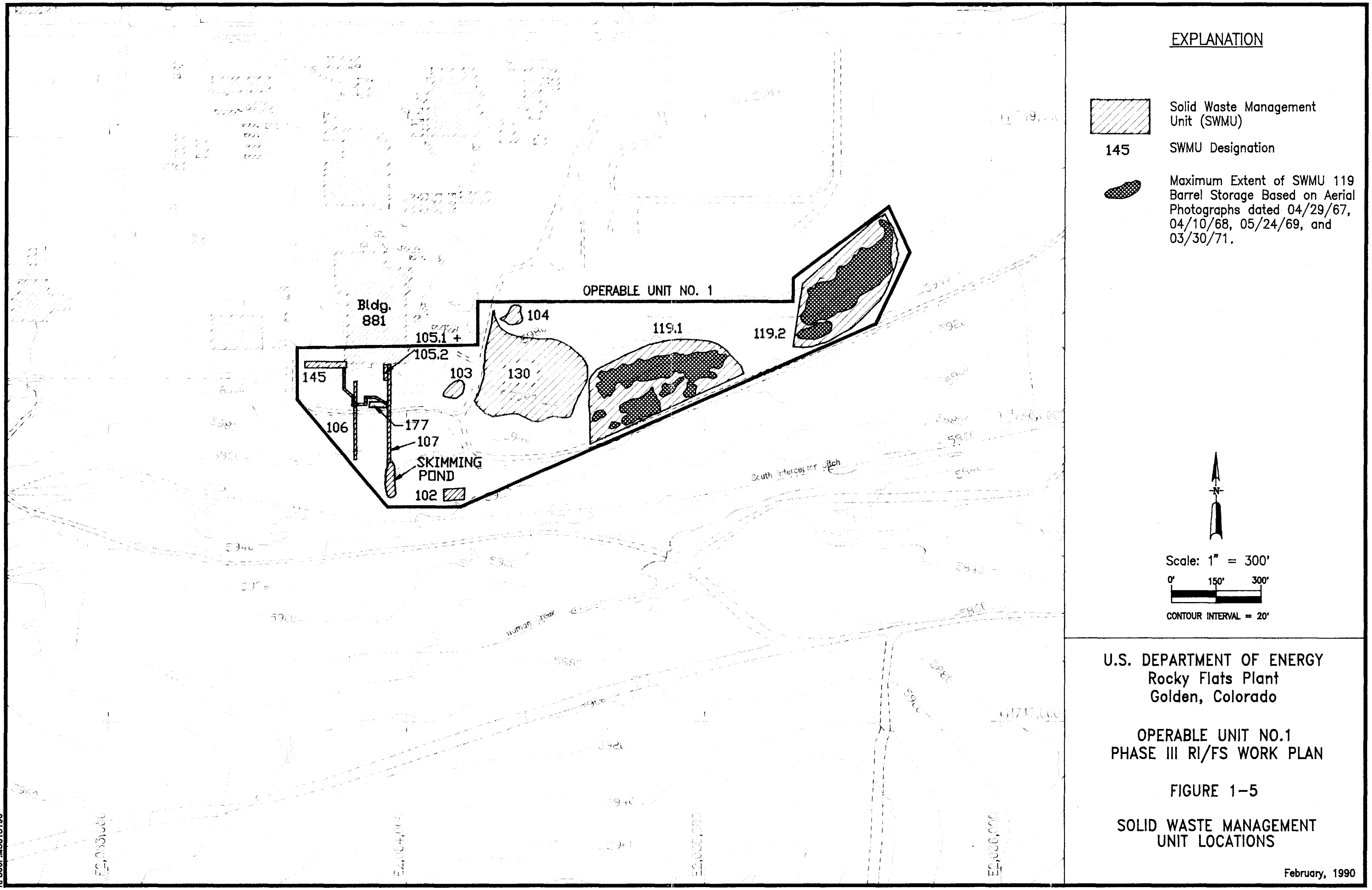
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-1

PHASE I AND PHASE II RI
BOREHOLE AND MONITOR WELL
LOCATIONS

February, 1990

RF300R.PJ-013190



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

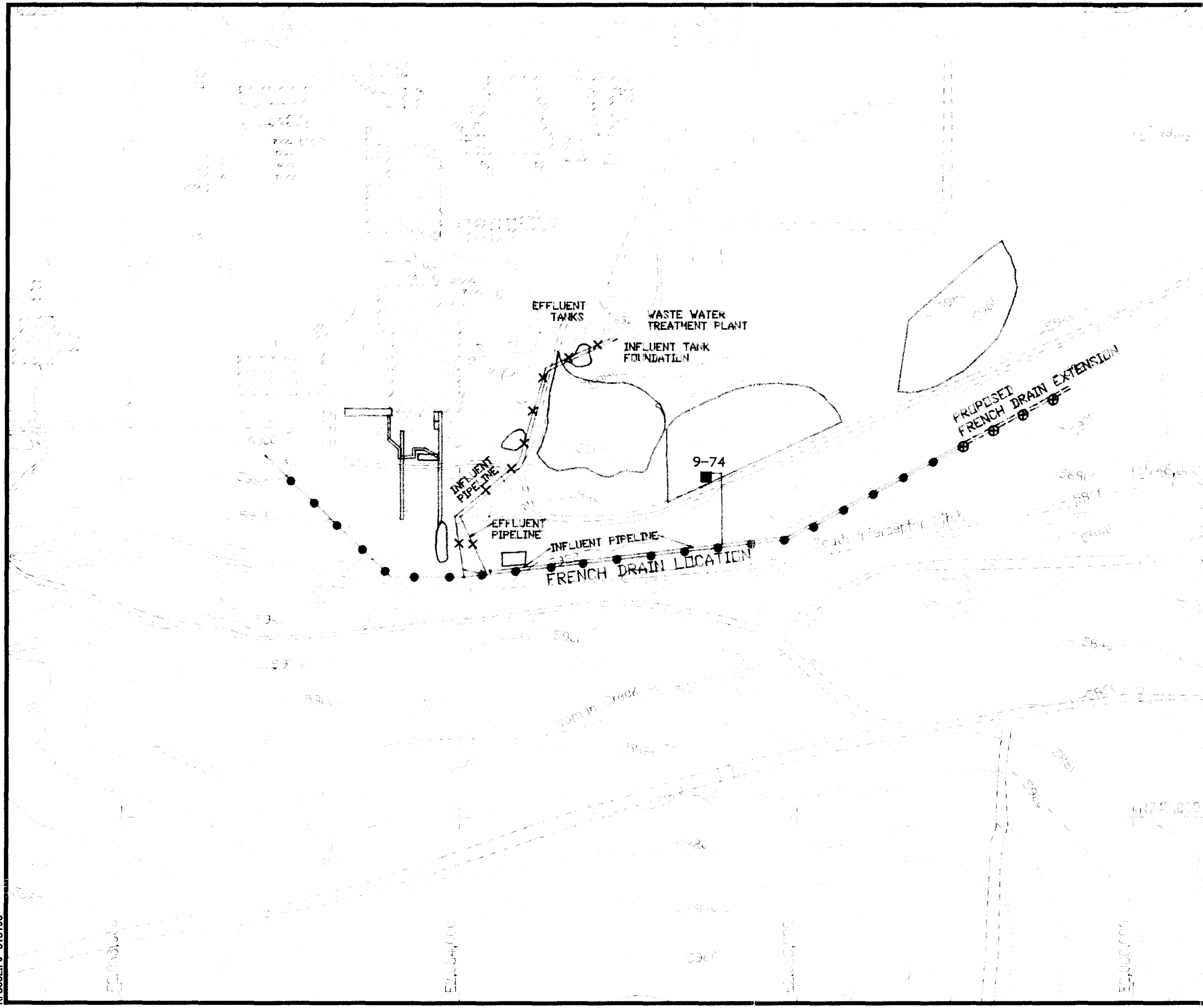
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 1-5

SOLID WASTE MANAGEMENT
UNIT LOCATIONS

February, 1990

RF300F.MB013190



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

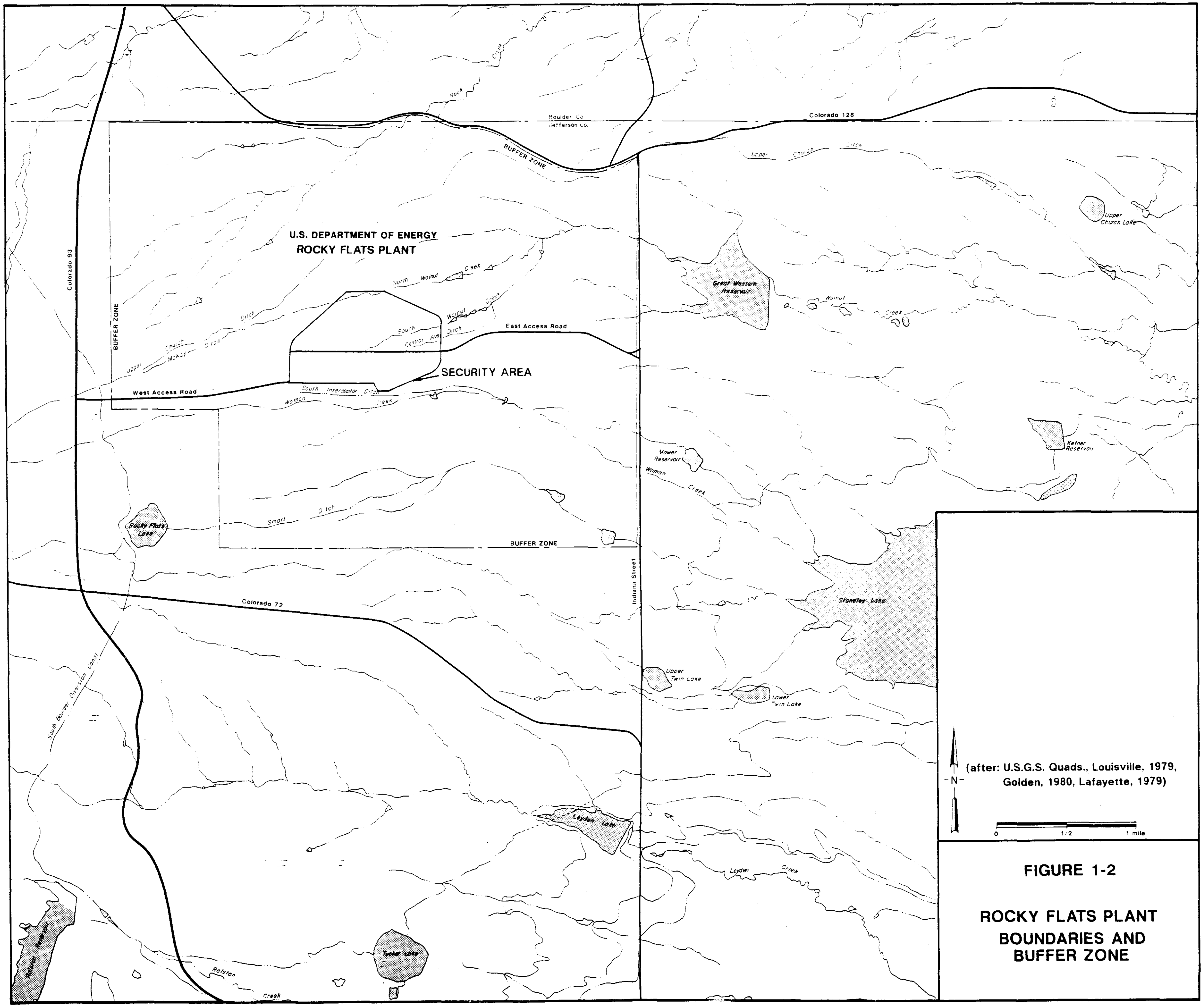
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 5-4

PROPOSED INTERIM REMEDIAL ACTION BOREHOLE LOCATIONS

February, 1990

RF300Z.PJ-013190



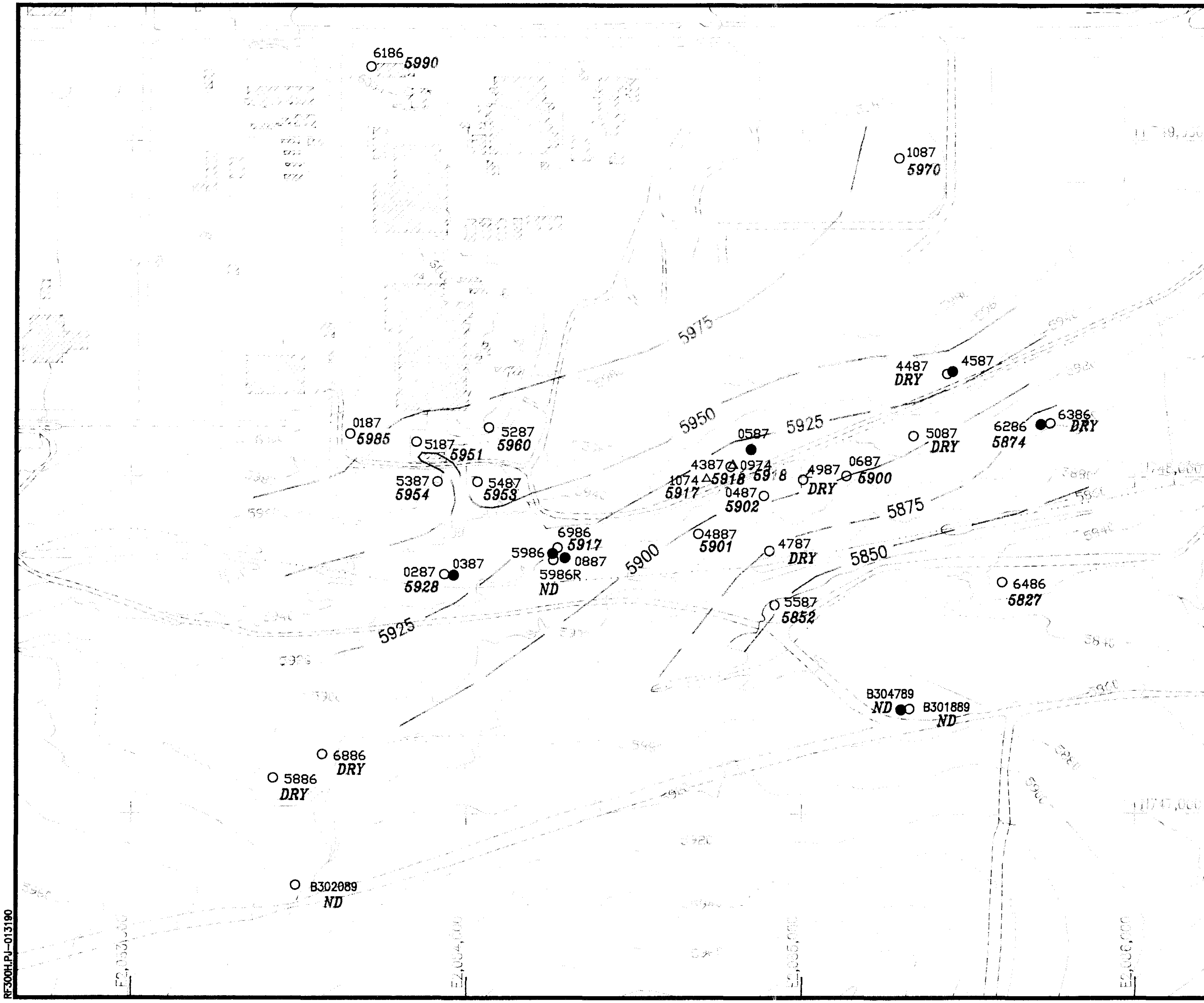
(after: U.S.G.S. Quads., Louisville, 1979, Golden, 1980, Lafayette, 1979)

0 1/2 1 mile

N

FIGURE 1-2

ROCKY FLATS PLANT BOUNDARIES AND BUFFER ZONE



EXPLANATION

B301889	O	Alluvial Monitoring Well
B304789	●	Bedrock Monitoring Well
0271	△	Pre-1986 Well
5851		Potentiometric Surface Elevation (feet above mean sea level)
5920		Line of Equal Potentiometric Surface Elevation (feet above sea level – dashed where approximately located)
ND		No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

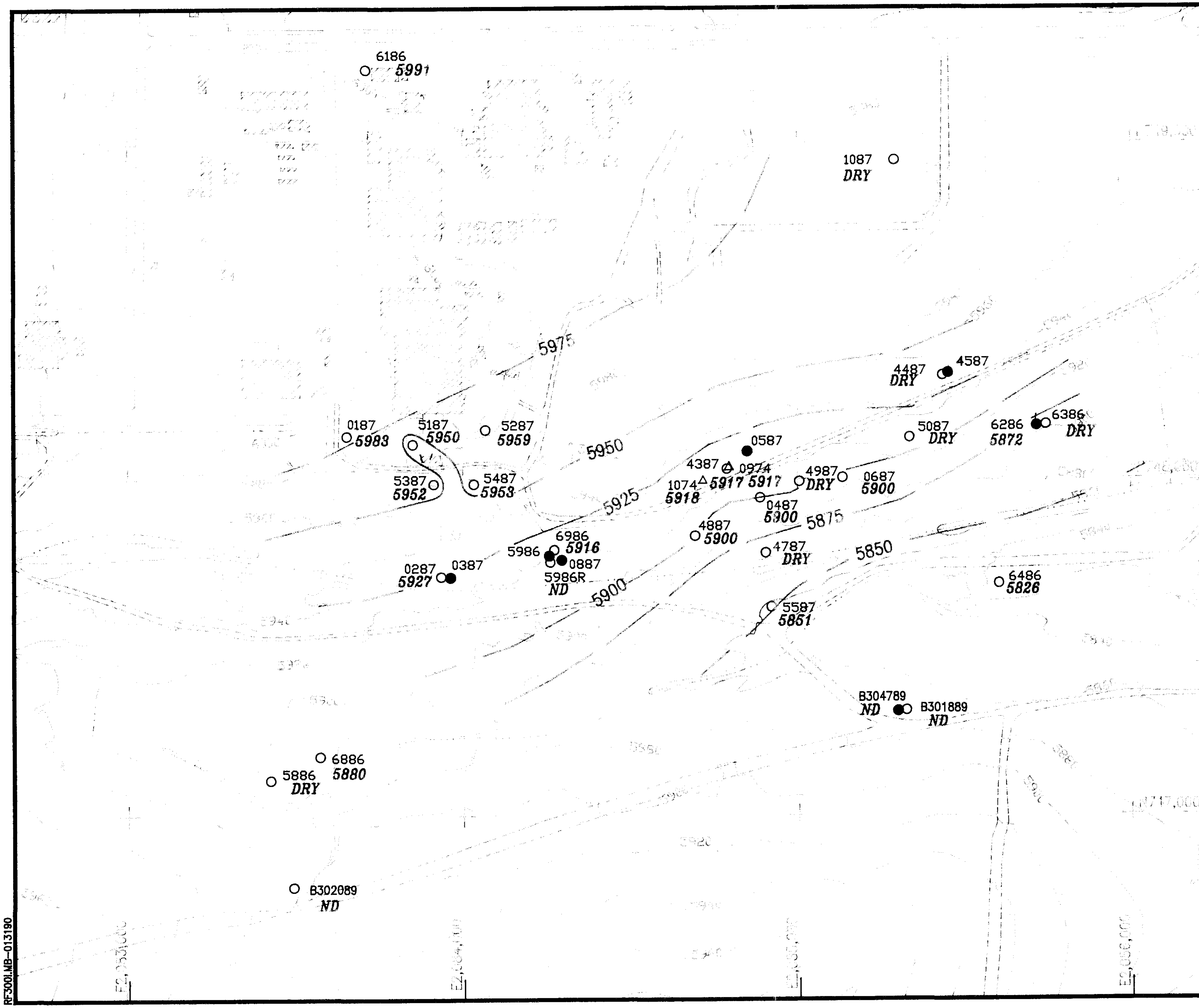
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-5

POTENTIOMETRIC SURFACE OF UNCONFINED GROUND-WATER FLOW SYSTEM
August 1988

February, 1990

RF300H.PJ-013190



EXPLANATION

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

5851 Potentiometric Surface Elevation (feet above mean sea level)

5920 Line of Equal Potentiometric Surface Elevation (feet above sea level – dashed where approximately located)

ND No Data – Well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

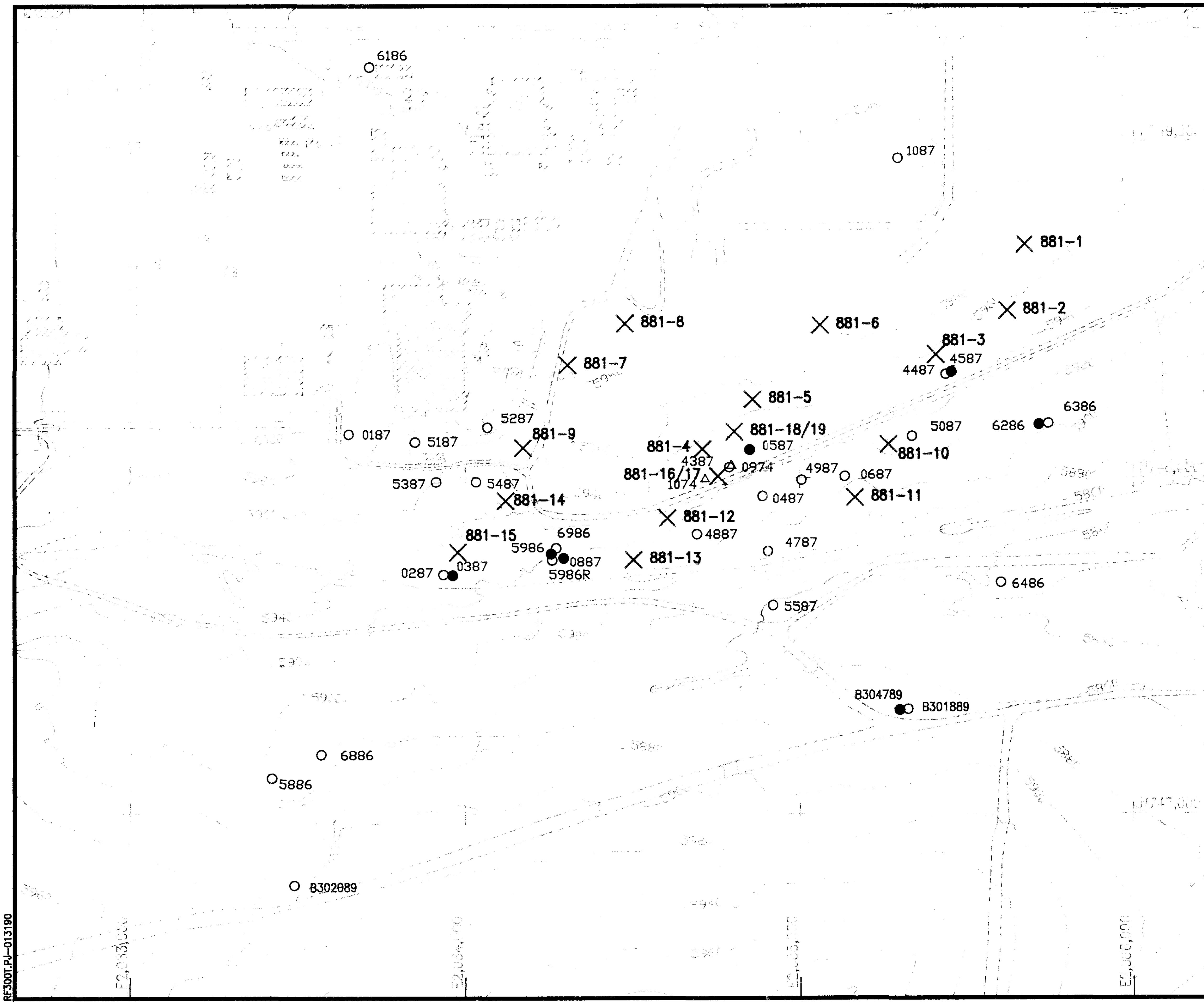
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-6

POTENTIOMETRIC SURFACE OF UNCONFINED GROUND-WATER FLOW SYSTEM
November 1988

February, 1990



EXPLANATION

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre–1986 Well

✕ 881–1 Approximate Surface Soil Scrape Location

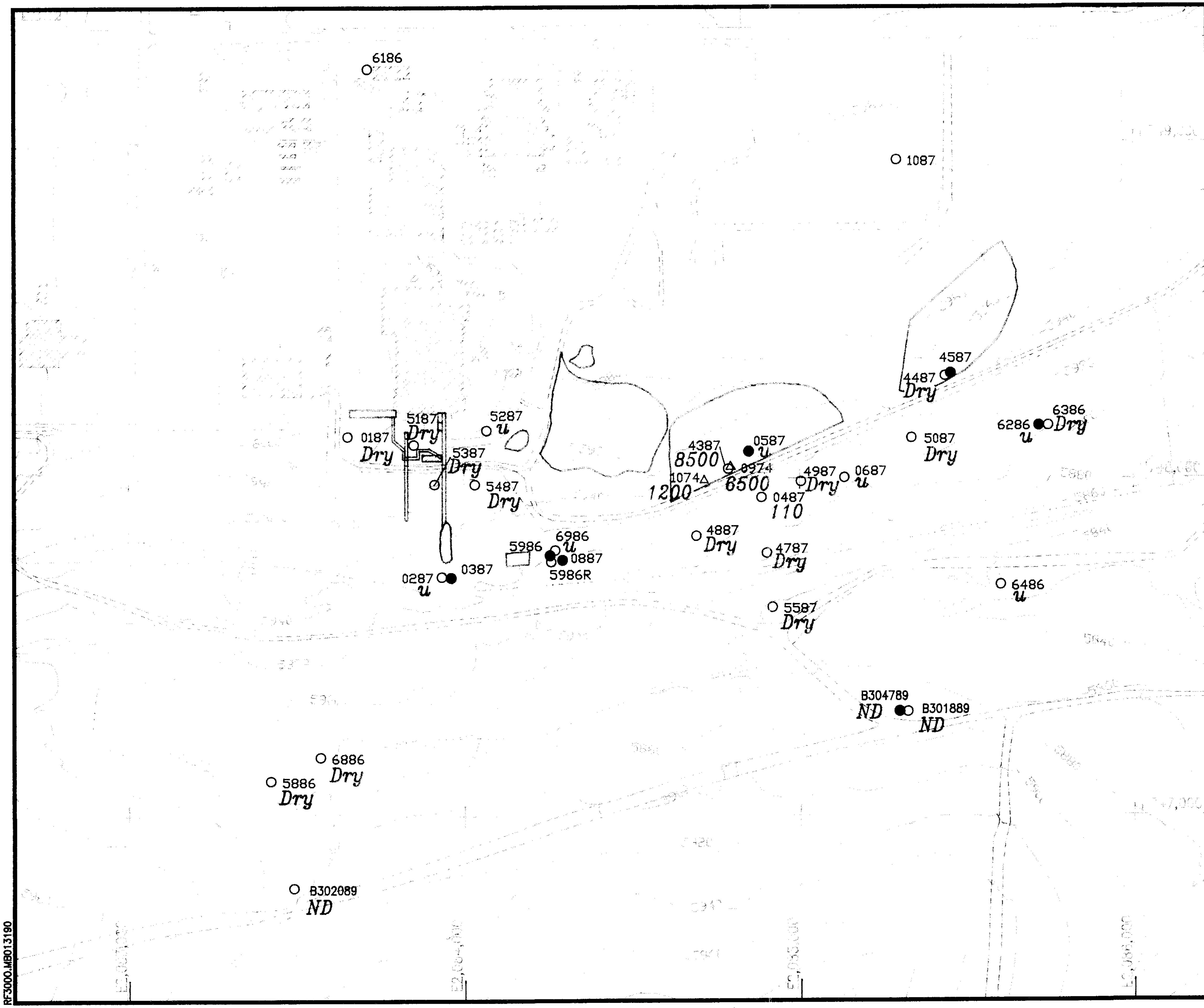
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-7

SURFACE SCRAPE SAMPLING LOCATIONS
September, 1988

February, 1990



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Trichloroethene Concentration:

35 Data in μg/l

u Analyzed but not Detected

ND No Data – Well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

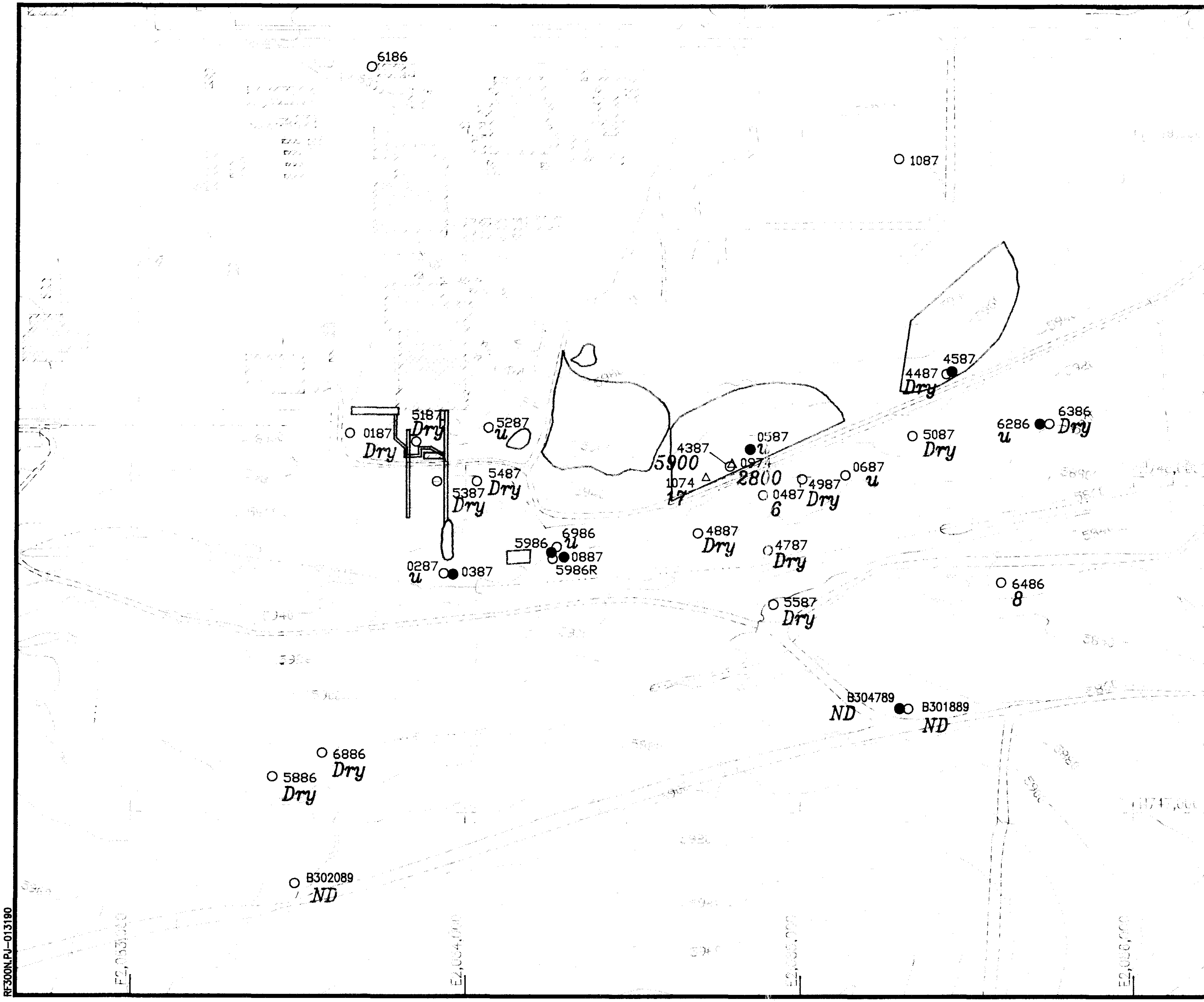
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-8

TRICHLOROETHENE CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

February, 1990

RF3000.MB013190



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Tetrachloroethene Concentrations:

6 Data in μg/l

u Analyzed but not Detected

ND No Data – well not yet completed

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

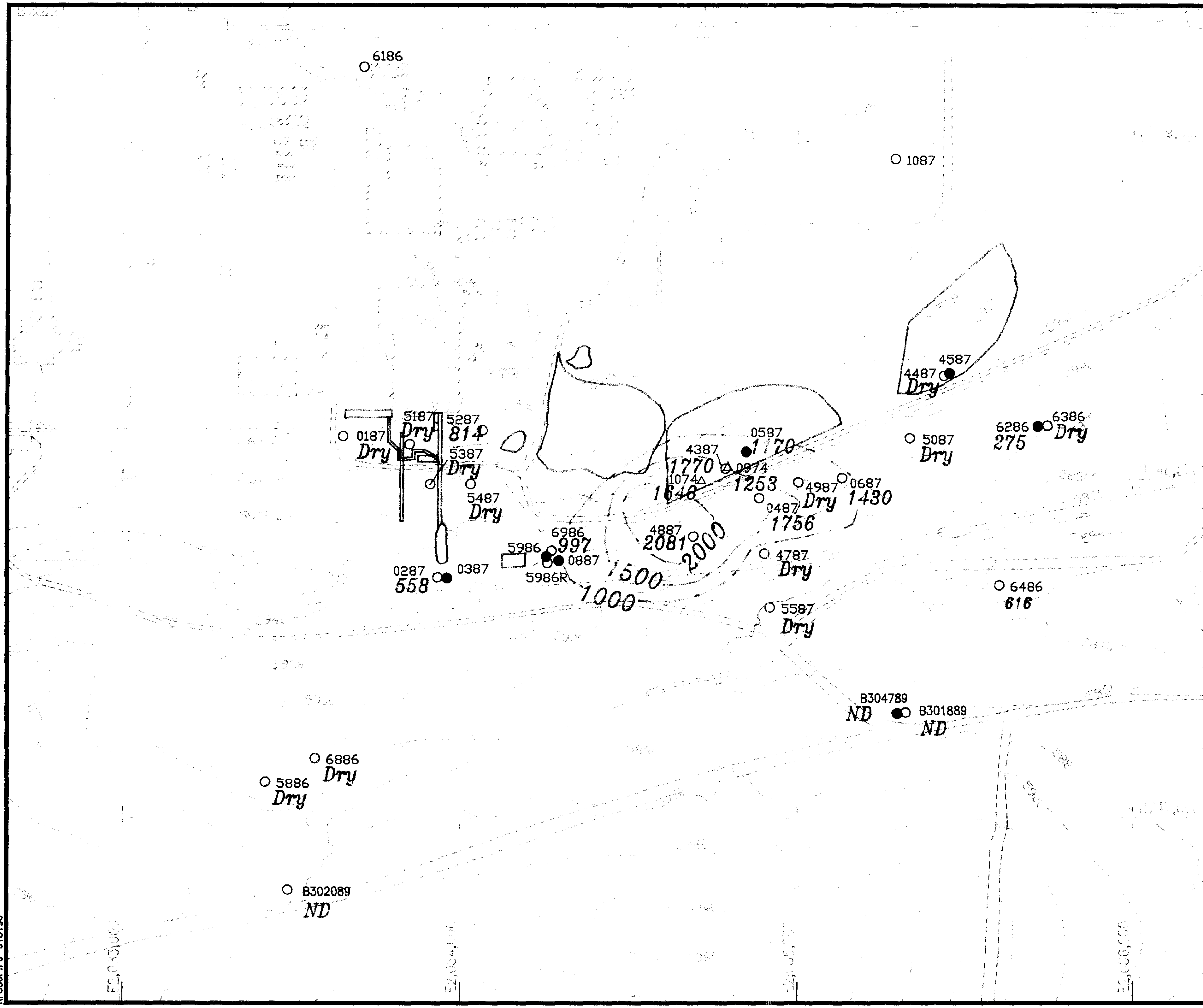
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-9

TETRACHLOROETHENE CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

February, 1990

RF300N.PJ-013190



EXPLANATION

▭	Solid Waste Management Unit (SWMU)
B301889 ○	Alluvial Monitoring Well
B304789 ●	Bedrock Monitoring Well
0271 △	Pre-1986 Well
1187A +	Abandoned Hole
997	Data in mg/l
1,000	Line of Equal TDS Concentration – Dashed where Approximately Located
ND	No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

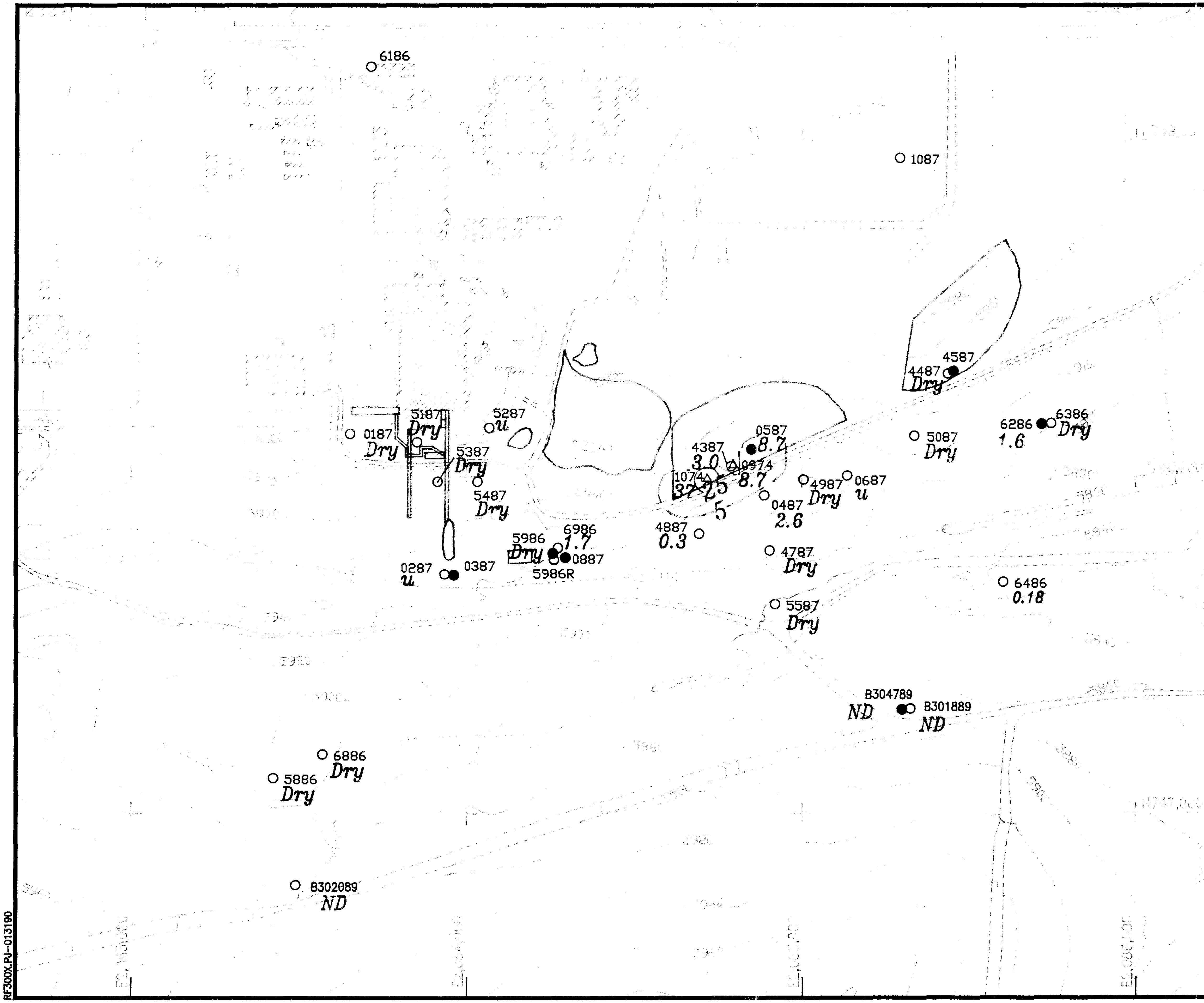
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-10

TOTAL DISSOLVED SOLIDS (TDS) ISOPLETHS FOR THE UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1989

February, 1990

RF300P.PJ-013190



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Nitrate Concentrations

8.7 Data in mg/l

5 Line of Equal Nitrate Concentrations – Dashed where Approximately Located

u Analyzed but not Detected

ND No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

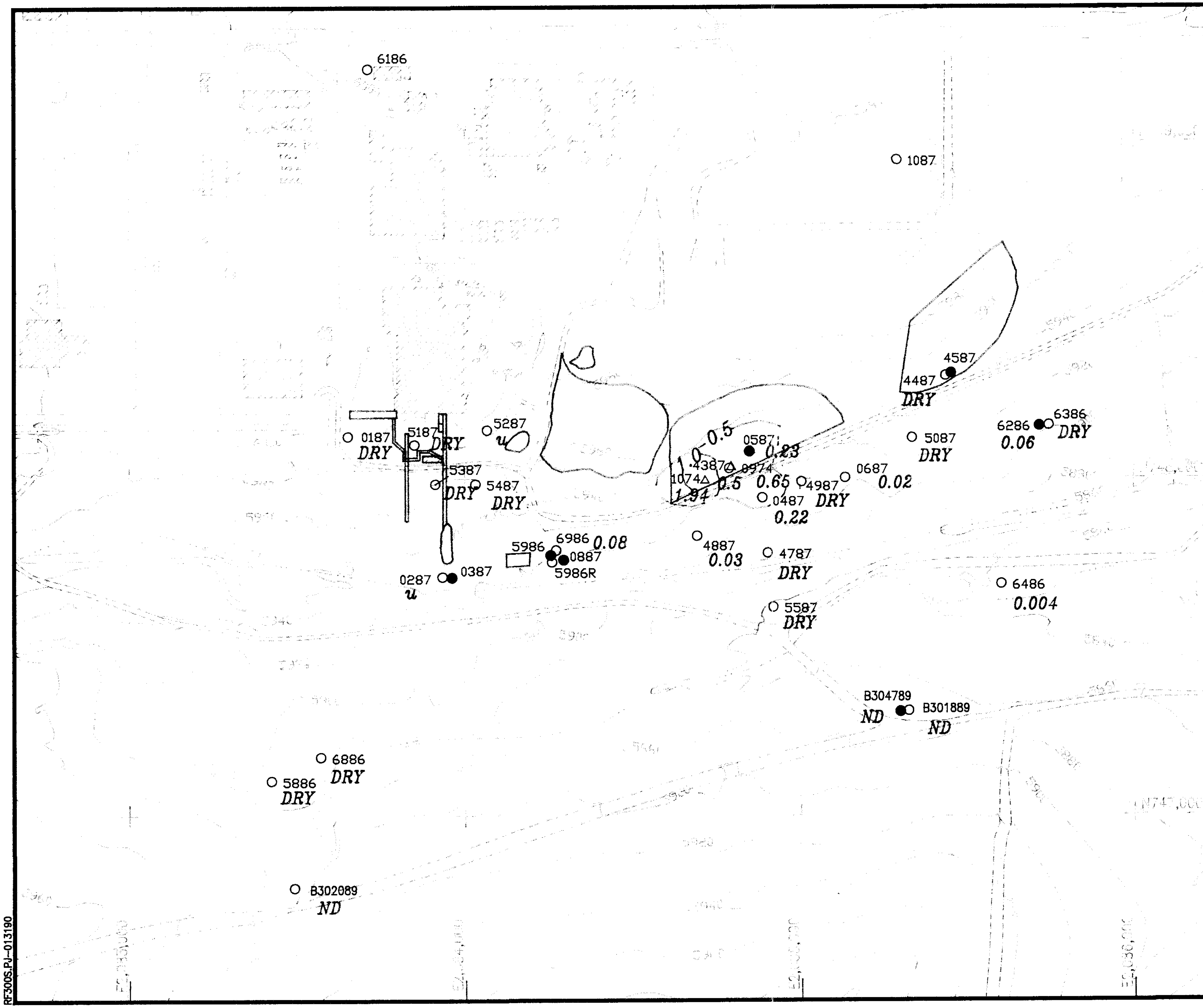
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-11

NITRATE CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1988

February, 1990

RF300X.PJ-013190



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Selenium Concentrations:

0.5 Data in mg/l

1.0 Line of Equal Selenium Concentrations – Dashed where Approximately Located

ND No Data – well not yet completed

u Analyzed but not Detected

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

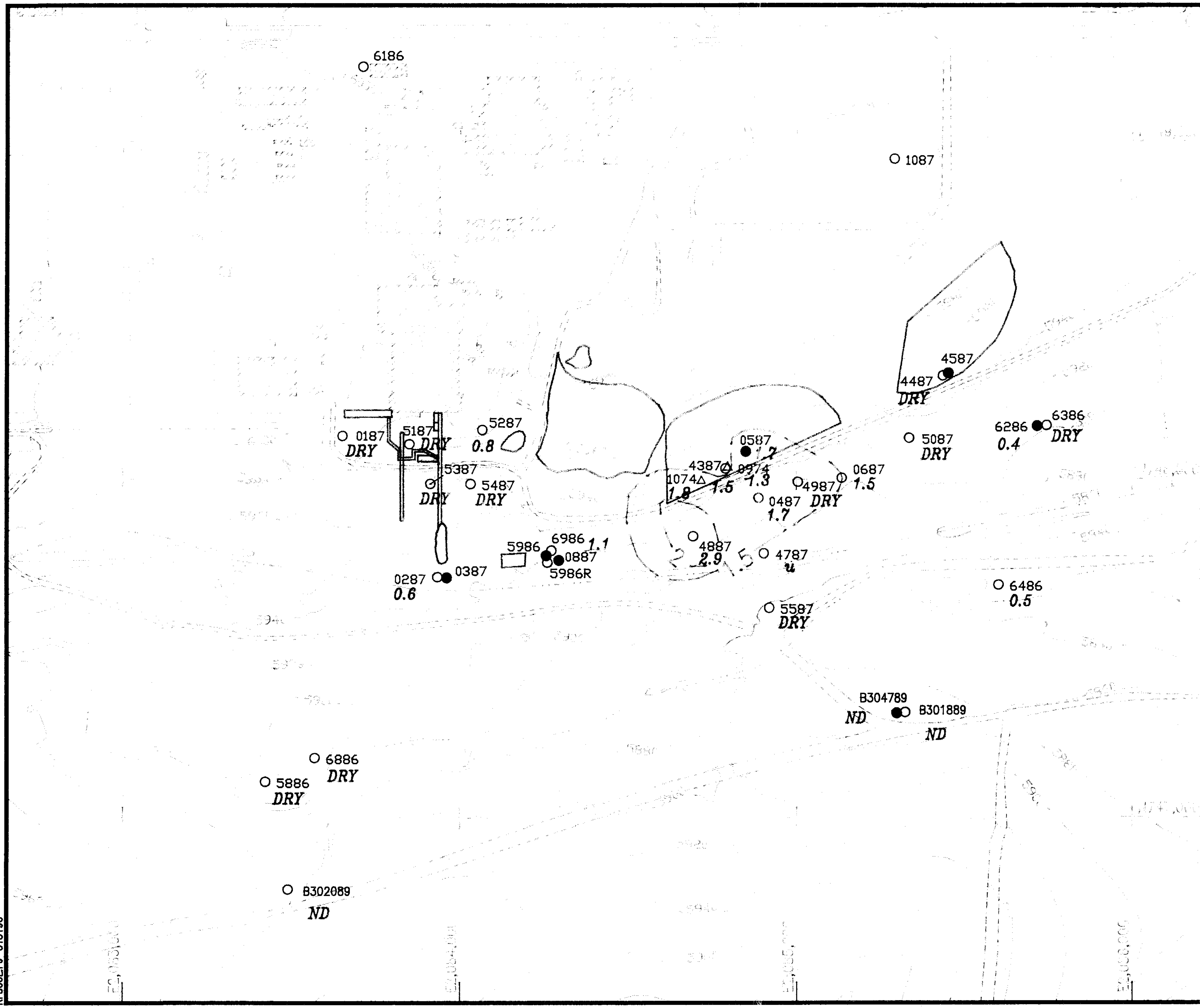
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-12

SELENIUM CONCENTRATIONS IN UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1988

February, 1990

RF300S.PJ-013190



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Strontium Concentration:

1.5 Data in mg/l

-1.5- Line of Equal Strontium Concentrations – Dashed where Approximately Located

u Analyzed but not Detected

ND No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

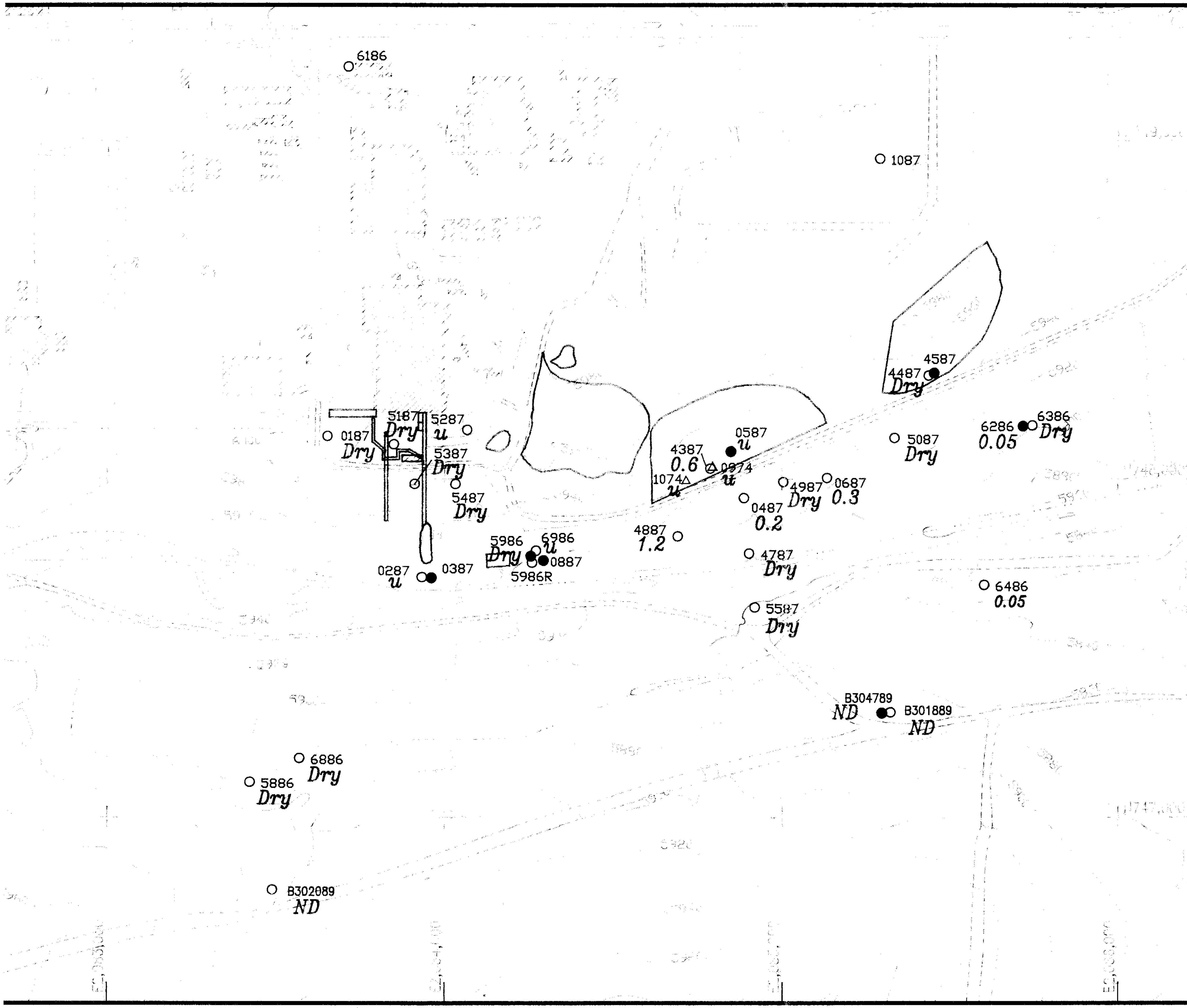
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-13

STRONTIUM CONCENTRATIONS IN UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1988

February, 1990



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Nickel Concentrations :

0.6 Data in mg/l

u Analyzed but not Detected

ND No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

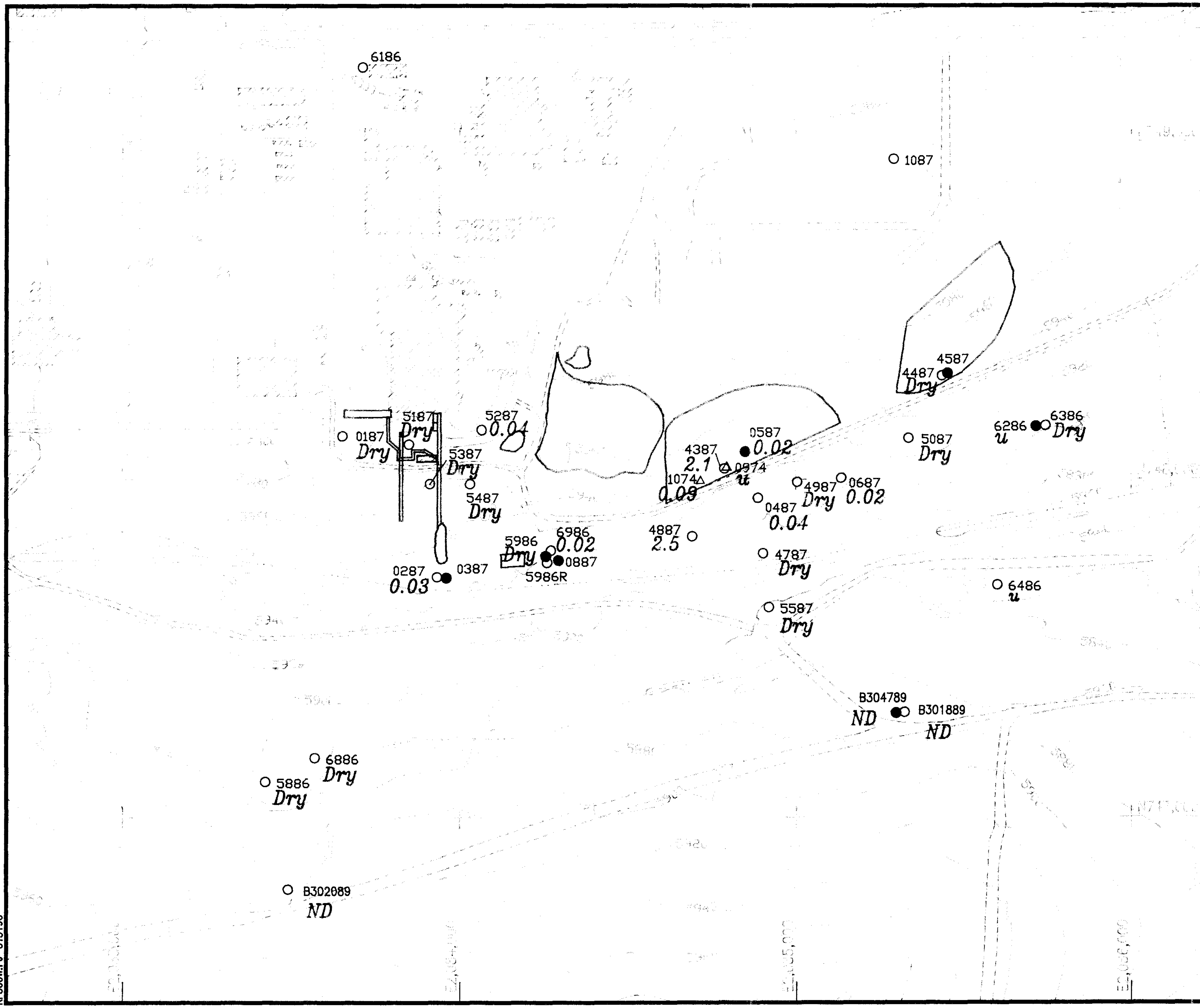
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-14

NICKEL CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1988

February, 1990



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Zinc concentrations

0.02 Data in mg/l

u Analyzed but not Detected

ND No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

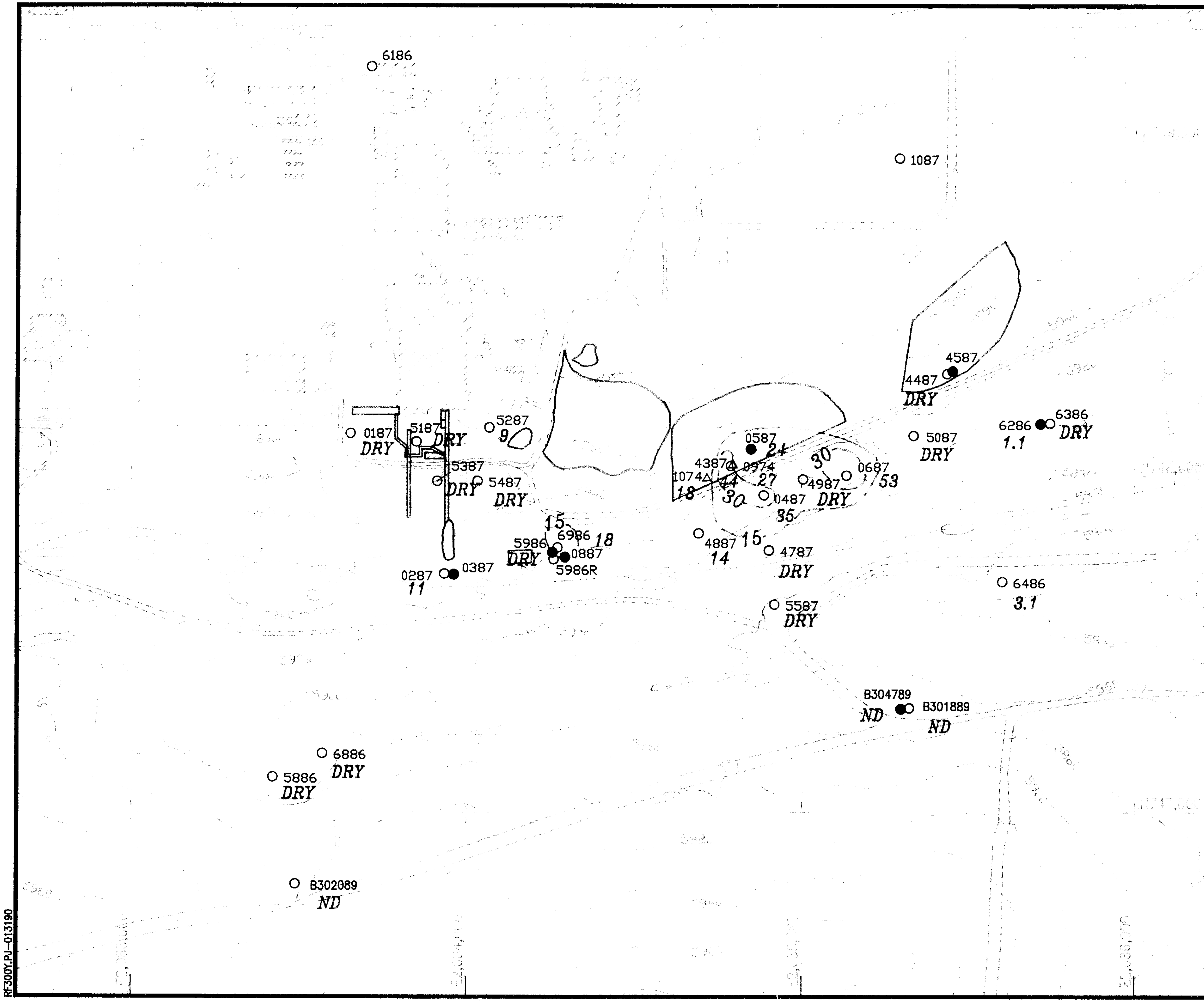
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-15

ZINC CONCENTRATIONS IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1988

February, 1990

RF300W.PJ-013190



EXPLANATION

Solid Waste Management Unit (SWMU)

B301889 ○ Alluvial Monitoring Well

B304789 ● Bedrock Monitoring Well

0271 △ Pre-1986 Well

Uranium Concentrations

1.1 Data in pCi/l

15 Line of Equal Total Dissolved Uranium Concentration – Dashed where Approximately Located

ND No Data – well not yet completed

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

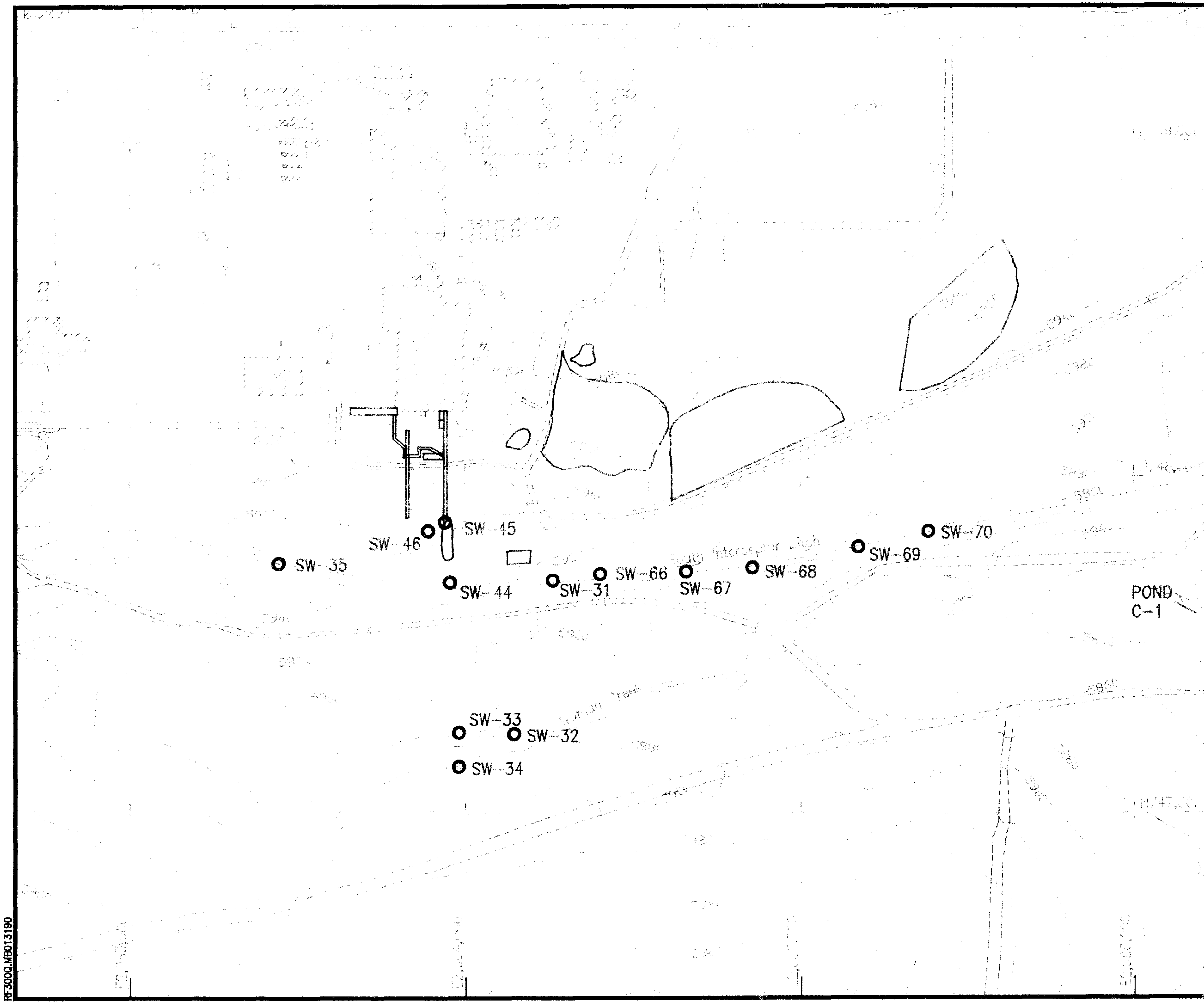
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-16

TOTAL DISSOLVED URANIUM IN THE UNCONFINED GROUND-WATER FLOW SYSTEM
First Quarter 1988

February, 1990

RF300Y.PJ-013190



EXPLANATION

Solid Waste Management Unit (SWMU)

SW-35 Surface Water Monitoring Station

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

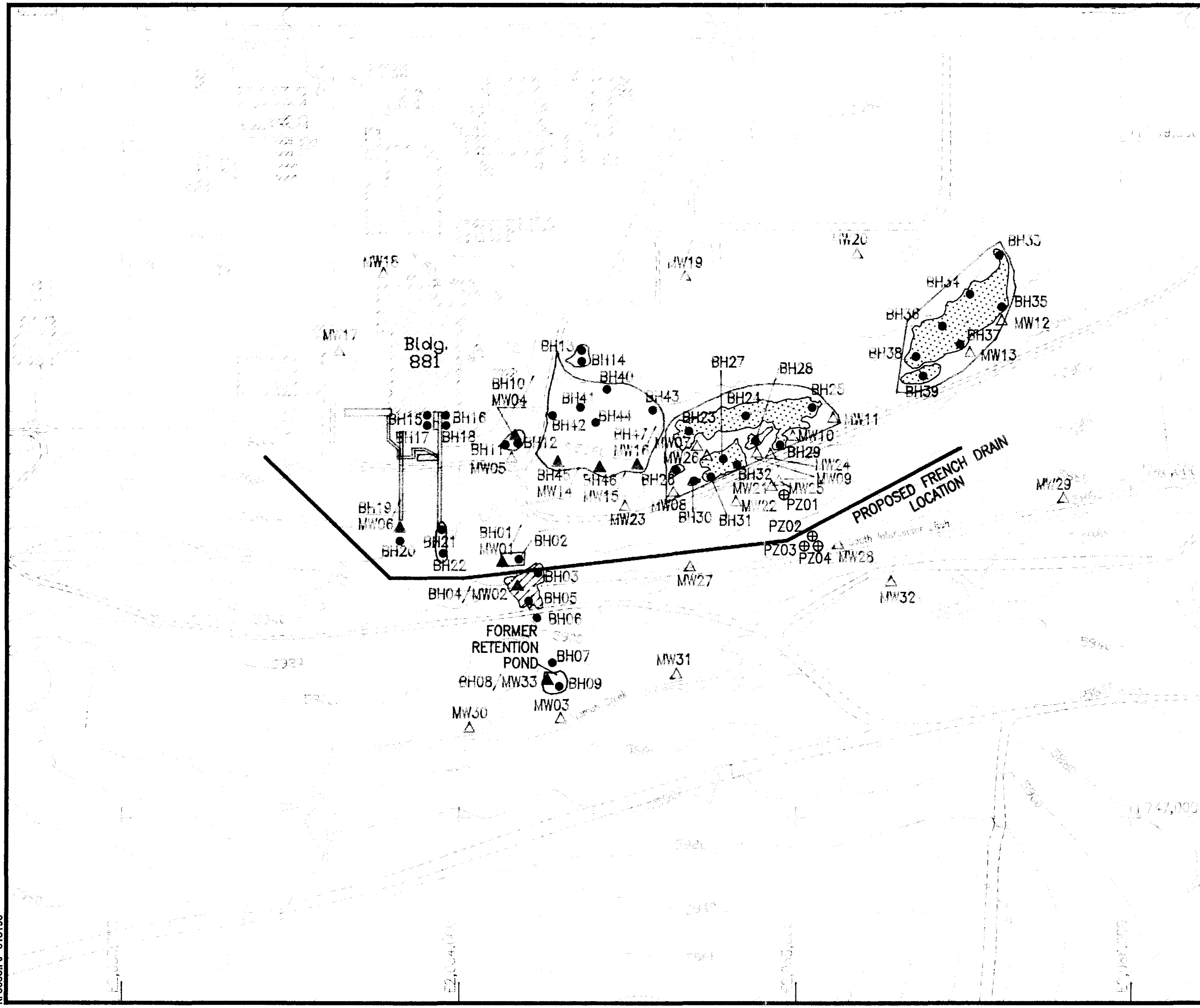
OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 2-17

SURFACE WATER MONITORING STATION LOCATIONS

February, 1990

RF300Q.MB013190



EXPLANATION

Solid Waste Management Unit (SWMU)

Seepage from SWMU 102 Based on Aerial Photographs Dated 05/11/55.

Maximum Extent of SWMU 119 Barrel Storage Based on Aerial Photographs dated 04/29/67, 04/10/68, 05/24/69, and 03/30/71.

Proposed French Drain Location

MW01 Proposed Monitor Well

BH01 Proposed Borehole

BH01/MW01 Proposed Borehole and Monitor Well

PZ01 Proposed Piezometer

N

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO.1
PHASE III RI/FS WORK PLAN

FIGURE 5-1

PROPOSED PHASE III RI
MONITOR WELL, BOREHOLE, AND
PIEZOMETER LOCATIONS

February, 1990

RF300U.PJ-013190